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STUDIES ON THE VARIATIONS IN THE STRUCTURE AND SIZE OF RAYS IN THE SECONDARY WOOD*

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(With one Plate)

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INTRODUCTION

It is already accepted that anatomical features of the stem and leaves of higher plants are of great value in taxonomy and that close collaboration between the anatomists and taxonomists is necessary for the correct identification of species. The taxonomic value of anatomy could be understood well only after a detailed study of the anatomical features of higher plants. The monumental work of Metcalf and Chalk (1950) provides all available anatomical facts about dicotyledons.

Sufficient work has not been done yet on the variations in the anatomical characters within a species. This is essential in order to find out whether there is a stable diagnostic anatomical feature for each genus and species.

Wood anatomists take into consideration the various wood elements such as vessels, fibres, rays and parenchyma for the purpose of identification. Essner (1883) has shown the ray distribution from the pith outward and from the bottom upward in the stem, variations among samples from the same species and differences between genus. Since then Baily and Fall (1934), Bannan (1937, 1941, 1942, 1944, 1950), Berkeley (1934), Fischer (1883) and Jaccard (1951) have studied the problem of variations within the tree or between specimens. Geiger (1915), Harlow (1927), Myer (1937) and Shope (1927) have investigated the problem of variations by the influence of environmental factors. The present paper is a study of the wood rays based on the investigation made on some of the dicotyledonous trees of South India. It explains the variation in the size and structure of the ray from the centre to the periphery at the same level and at different levels of a tree trunk.

MATERIAL AND METHOD

The material for the study was collected from living trees of the forest in Travancore, South India. Five trees of each species which

* Taken from the Thesis "Studies on the Anatomy of South Indian Timbers," approved for the Ph.D. Degree of the University of Edinburgh.

belong to different genera and families were selected. Discs were cut (a) from the base of the trunk one foot above the soil surface and (b) from the top of the trunk one foot below the first branching.

The distance between the upper disc and the lower disc is almost the same in all the five trees of each species. Blocks of wood $1\frac{1}{2}$ cm. \times 1 cm. \times 1 cm. were cut at a distance of 1 inch from one another for sectioning. They are cut from the same radius, from the centre to the periphery of the upper and lower discs. Thus Block No. 1 is the innermost block just at the beginning of the secondary wood and the rest are numbered in order of their position towards the outside. Tangential sections from each block were taken in suitable thickness to study the height, width and the structure of the rays.

The species selected were:—

- (1) *Pajanelia rheedi* Wight.
- (2) *Erythrina stricta* Roxb.
- (3) *Macaranga peltata* Muell Arg.
- (4) *Tabernamontana dichotoma* Roxb.
- (5) *Anacardium occidentale* Linn.

OBSERVATIONS AND DISCUSSIONS

A detailed study of the rays in the materials under investigation show the following results which are recorded in tables. Each table explains the height and width of the ray (all measurements in μ) in the various blocks from the centre to the periphery in different levels of the tree trunk.

TABLE I. *Pajanelia rheedii*

Lower					Upper			
	Block No.	Min.	Mean	Max.	Block No.	Min.	Mean	Max.
Height of the ray	I	133	305.7	567	I	111	233	456
	II	111	279	500	II	200	293.5	500
	III	111	305	611	III	156	273	478
	IV	178	393	689				
	V	222	401	678				
Width of the ray	I	44	48	66	I	22	44	55
	II	33	47	56	II	56	63	77
	III	44	60	67	III	67	74	89
	IV	55	58	67				
	V	44	53	56				

TABLE II. *Macaranga peltata*

Lower					Upper			
	Block No.	Min.	Mean	Max.	Block No.	Min.	Mean	Max.
Height of the ray	I	556	1056	1611	I	444	885	1337
	II	444	1231	2311	II	711	957	1499
	III	556	1314	2778	III	444	897	1444
	IV	600	1156	2000	IV	455	923	1444
	V	256	1041	2444	V	233	966	1311
Width of the ray	I	11	16	22	I	11	16	22
	II	22	25	44	II	11	18	22
	III	22	32	44	III	11	20	22
	IV	22	32	33	IV	22	24	33
	V	22	47	100	V	11	29	44

TABLE III. *Erythrina stricta*

Lower					Upper			
	Block No.	Min.	Mean	Max.	Block No.	Min.	Mean	Max.
Height of the ray	I	778	1364	1844	I	777	1593	2444
	II	611	1362	1988	II	777	1779	3000
	III	591	1461	2222	III	577	1437	2166
	IV	633	992	1770	IV	889	1345	2188
	V	422	932	2044				
	VI	399	1219	1833				
Width of the ray	I	88	130	222	I	56	71	111
	II	77	110	133	II	78	133	200
	III	144	186	222	III	78	200	255
	IV	122	153	166	IV	133	215	266
	V	122	200	278				
	VI	222	273	344				

TABLE IV. *Tabernæmontana dichotoma*

Lower					Upper			
	Block No.	Min.	Mean	Max.	Block No.	Min.	Mean	Max.
Height of the ray	I	333	498	667	I	433	579	778
	II	611	708	933	II	389	767	1167
	III	500	664	778	III	333	539	1167
	IV	389	553	889	IV	344	540	556
	V	333	483	778				
Width of the ray	I	33	44	56	I	33	40	44
	II	33	42	44	II	33	44	56
	III	44	55	67	III	44	53	56
	IV	44	54	56	IV	44	53	56
	V	56	73	100				

TABLE V. *Anacardium occidentale*

Lower					Upper			
	Block No.	Min.	Mean	Max.	Block No.	Min.	Mean	Max.
Height of the ray	I	156	504	889	I	333	475	922
	II	222	452	711	II	289	499	667
	III	288	427	678	III	256	405	867
	IV	222	590	555	IV	256	429	867
	V	244	426	677	V	278	430	733
	VI	300	466	788				
	VII	155	359	556				
Width of the ray	I	22	42	78	I	33	38	44
	II	44	52	78	II	33	44	56
	III	33	44	67	III	33	44	56
	IV	44	54	67	IV	33	44	56
	V	33	44	56	V	33	45	56
	VI	33	45	56				
	VII	33	47	67				

From the above tables it is clear that the mean height of the ray in the inner block is greater than that of the outer block in all the species except in *P. rheedii* and the upper portions of *M. peltata*. The reduction in the height towards the outside is not gradual and at the same time it does not take any definite course of change even in those trees where such a reduction is noted in the outer block. The decrease in such cases is not always very appreciable. Thus in *E. stricta* there is only a reduction by 10.7% at the lower region and 18.4% at the upper region; in *T. dichotoma* 8.27% at the lower region and 6.7% at the upper and in *A. occidentale* 27.7% at the lower region and 9.6% in the upper region.

It is noted that the height of the ray is very highly variable from place to place along the same radius of the same level and in different levels of the tree trunk.

From the tables it is also seen that the mean width of the ray increases towards the outside in all the trees in the lower and upper levels. In some cases the increase in width is noted as gradual from the inner block to the outer block and in some others it is not gradual. The rays in the outer blocks show a great increase over those of the inner block. In *P. rheedii* the increase is by 10.4% at the base and 68.2% at the top; in *M. peltata* it is by 193.75% at the base and 81.2% at the top; in *E. stricta* 110% at the base and 202.5% at the top; in *T. dichotoma* 65.9% at the base and 32.5% at the top; and in *A. occidentale* it increases by 11.9% at the base and 5.3% at the top.

A detailed examination of the structure of the rays helps to explain the reasons for this increase in mean width of the ray.

In *P. rheedii* the structure of the rays shows variations. It is observed that most of the rays in the inner block are 2-seriate but a few uniseriate rays occur, whereas in the outermost block they are 3-seriate, few 2-seriate and very few uniseriate. The size of the individual cells of the ray does not show noticeable difference between the inner and outer wood. The characteristic type (Type II A Kribs) of the ray remains constant in all the blocks from the centre outward in different levels.

In *M. peltata* both uniseriate and biseriate rays occur in the innermost block. In the outermost block they are mostly 3-seriate, few 2-seriate and rarely uniseriate; 4-seriate or 5-seriate rays also occur in the outer blocks. The individual cells of the ray in this case enlarges considerably towards the outside from the centre. In the inner block the maximum width of the ray cell is 11μ whereas in the outermost block the ray cells attain a maximum width of 28μ . The ray type (Heterogeneous type I Kribs) remains constant in all the blocks.

In *E. stricta* the rays in the innermost block are narrow often 4-8 cells wide. In the outer block the rays are broader 4-15 cells wide. Uniseriate rays occur in all the blocks. The ray cells have a maximum width of 44μ in the inner wood, though such cells occur very seldom. In the outer blocks the ray cells attain a size of 55μ and the number of larger cells are greater in each ray. The ray type (Heterogeneous Type II A Kribs) does not undergo any change.

In *T. dichotoma* the innermost block consists of mostly multi-seriate rays of 3-4 cells wide. Triseriate rays are more frequent. In the outermost block the rays are mostly 4-seriate or 5-seriate. Uniseriate rays occur in all the blocks. The ray cells in the inner block attain only a maximum of $22\ \mu$ in width whereas in the outer they reach $44\ \mu$. Such larger cells are numerous in the rays towards the periphery.

The ray type (Heterogeneous type II A Kribs) remains unchanged in all.

In *A. occidentale* most of the rays are uniseriate and few biseriate in the inner block and in the outer they are mostly biseriate. Here there is no appreciable difference between the size of individual cells of the rays belonging to the inner and outer blocks at the same level.

From the above observations it is clear that in all cases the increase in the mean ray width towards the periphery is mainly due to the increase in the number of cells that constitute the width of the ray. Besides it is also noted that the rays do not exceed certain limits regarding their width which is probably a characteristic maximum width. The occurrence of such rays of maximum size in the outer block is not constant. The transitional sizes from the smallest to the largest are found in the outer blocks too. The percentage of smallest rays is always found to be less in the outer regions than the inner. Hence an increase in mean width is noted in the outer regions. It is also clear that this increase in the mean width of the ray is subject to the frequency of wider rays in a particular region. Therefore there is always a change in the mean width of the rays from place to place. The gradual increase in the width of the ray is also due to the enlargement of few individual cells that constitute the ray as noted in the various materials. The plate shows the size of the rays in the inner and outer regions at the same level.

The ray type, characteristic of the species remains constant in all the blocks.

It is also observed that as the rays become broader they become shorter in all the trees studied excepting in *P. rheedii* and upper portions of *M. peltata*.

The foregoing observations explain the nature and the changes in the size of the rays from the centre to the periphery in certain tree trunks.

Many wood anatomists consider the nature of the rays as a reliable character for the identification of wood. Barghoorn (1941) disagrees with this. The observations made above support the conception that the ray structure is a diagnostic character. It is made clear that though the height and width of the ray undergo changes as the tree grows, the structure of the ray does not undergo changes to the extent of altering the specific type. De Bruyne (1952) has noted an increase in width of the ray in the tree trunk from the centre to the periphery along the same radii. He maintains that the rays of two species of *Pterospermum* are found to change in size and structure at different ages

of the tree. In the trees studied above the size of the ray varies and the type structure remains constant.

SUMMARY

The height of the ray is different in various places in the same level and in different levels of the tree trunk. A slight decrease in height is noted in some trees in the outer wood from that of the inner wood.

The mean width of ray undergoes a gradual increase towards the periphery from the centre along the same radius. This increase is largely due to the increase in the number of series of cells constituting the width of the ray and slightly due to the increase in the size of certain cells of the rays in the outer region. The width of large rays in the outer region does not exceed certain probable maximum limits for the species. The percentage of larger rays is greater in the newly formed wood. Hence the mean width increases to the outside.

The type character of the ray remains constant in lower and upper portions from the centre to the periphery. Hence it forms a reliable feature for identification of the wood.

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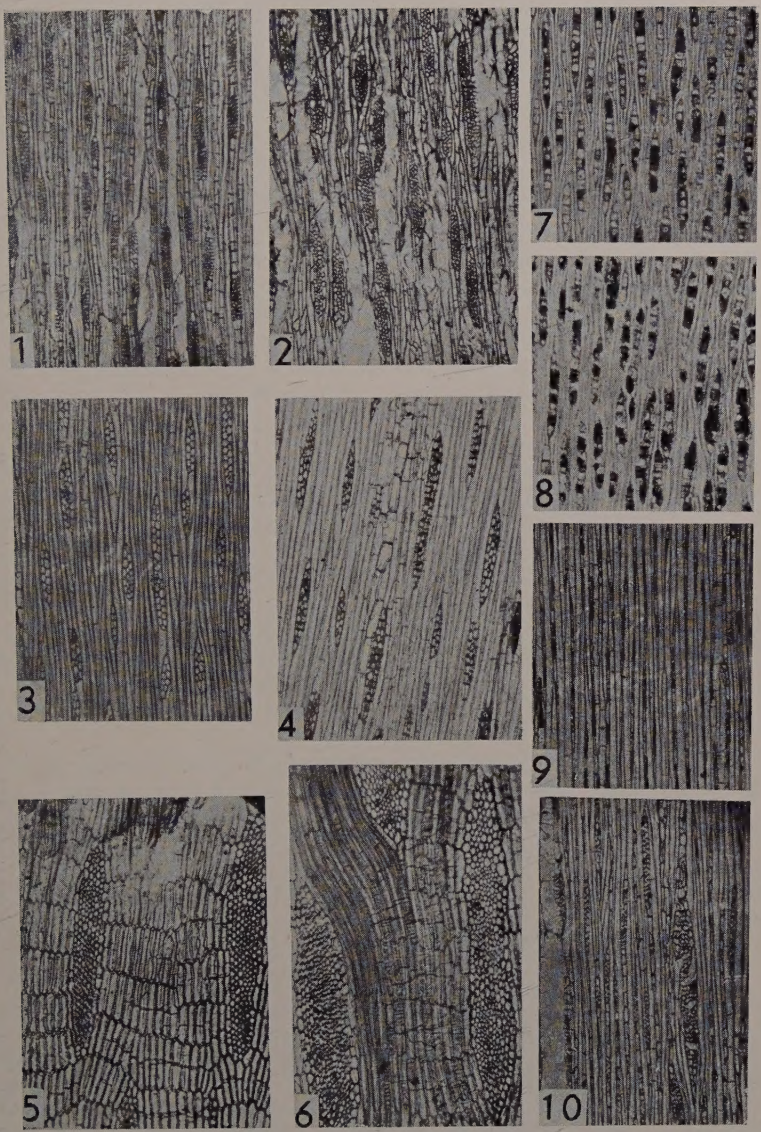
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LEGENDS FOR THE PLATE

FIGS. 1-10. Figs. 1-2. *Tabernaemontana dichotoma*. Figs. 3-4. *Pajanelia rheedii*. Figs. 5-6. *Erythrina stricta*. Figs. 7-8. *Anacardium occidentale*. Figs. 9-10. *Macaranga peltata*.

1, 3, 5, 7, 9 Inner blocks. 2, 4, 6, 8, 10 Outer blocks. T.L.S., $\times 28$.



A CONTRIBUTION TO OUR KNOWLEDGE OF THE FRESH-WATER DIATOMS OF PARTABGARH, RAJASTHAN

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(Received for publication on February 6, 1955)

INTRODUCTION

WHILE going through introductions given by Venkataraman (1939), Subrahmanyan (1946), Gonzalves and Gandhi (1952) and Krishnamurthy (1954) who have surveyed the available information on the Indian Diatomaceæ, it becomes evident that nowhere any record of Diatoms of Rajasthan and particularly of that of Partabgarh exists. The author, therefore, got interested to undertake the work.

LOCATION OF PARTABGARH

Partabgarh—once a Native State, better known as Deolia-Partabgarh, is situated on the extreme South of Rajputana (now Rajasthan), lies between $23^{\circ} 32'$ and $24^{\circ} 18'$ North and $74^{\circ} 29'$ and 75° East and has an area of 886 square miles. It is bounded on the North and North-West by Udaipur*; on the West and South-West by Banswara*; on South by Ratlam† and on East by Jaora,‡ Scindhia's districts of Mandsaur† and Neemuch and a detached portion of the Rampura-Bhanpura districts of Indore.‡ Leaving the North-West part which is rocky and wild, the whole area is a fine open land.

GEOLOGY

A large proportion of Partabgarh is covered with the Deccan Trap, the denudation of which has exposed underlying area of older rocks belonging to the System, such as shales, quartzites, limestones, etc.

CLIMATE AND RAINFALL

The climate is generally good and the temperature moderate. The average annual rainfall as recorded at the capital (Partabgarh) is a little over 34 inches. The highest record of 63 inches in 1893 and the lowest of 11 inches was registered in 1899.

A BIT OF HISTORY

The town Partabgarh is situated in $24^{\circ} 2'$ North and $74^{\circ} 47'$ East, twenty miles by a metalled road west of Mandsaur Station on the Western-Railway. This town was founded by and named after Maharawat Pratapsingh in 1698, has 1,660 feet elevation above the sea-level, in a hollow formerly known as "Deolia-ka-khera". It is defended by a fortification all around, built by Salimsingh in about 1758.

* All these places now make Rajasthan Union.

† All these States and places are embodied into Madhya Bharat Union.

PLACE OF COLLECTION

Very close to the fortification stated above, rain-water streams flow all around and meet into a rivulet Jakam which pours into the Som tributary of the Mahi River. These rain-fed streams continue their flow till the end of November when the rainfall is well distributed, otherwise they dry up entirely by the end of October except for some bigger pools and ditches. The author, during his 1949-52 Diwali vacations had collected the present material from several such bodies of water of the drying streams. The water of these pools and ditches is generally polluted and non-potable.

The present investigation was carried out in the Biology Departments of the Ismail Yusuf College, Jogeswari, Bombay and the Rajaram College, Kolhapur. The interesting feature of the material noted is the preponderance of *Surirella ovata* Kütz., with some degree of variation in its outline. Of other more important forms, mention must be made of *Navicula krasskei* Hust., *N. fluens* Hust., *Caloneis clevei* (Lagst.) Cl., *C. bacillum* (Grun.) Meresch., *Cymbella aspera* (Ehr.) Cleve, *Nitzschia frustulum* Kütz. and *N. amphibia* Grun., whereas others included in this paper may be regarded as just present or rare forms. A few frustules of *Caloneis permagna* (Bailey) Cleve present in the material were found to be most beautiful specimens.

All the drawings were made from the slides prepared in canada balsam with the help of camera-lucida.

The classification adopted here is that of Hustedt (1930). All those references which have been actually consulted are given under the several forms.

The locality marked (!) thus, is the one from where the author has collected the material.

BACILLARIOPHYTA (DIATOMEÆ)

A. Order	CENTRALES
I. Sub-order	DISCINEÆ
1. Family	COSCINODISCACEÆ
(a) Sub-family	COSCINODISCOIDEÆ
Genus	<i>Cyclotella</i> Kütz. 1834

1. *Cyclotella meneghiniana* Kütz.

(Fig. 1)

Van Heurck, *Treatise on the Diatomaceæ* (Trans. by Baxter), 1896, p. 447, pl. 22, fig. 656; Schönfeldt, H., Pascher's *Süßwasser-Flora*, Heft 10, 1913, p. 19, fig. 17; Hustedt, F., Pascher's *Süßwasser-Flora*, Heft 10, 1930, p. 100, fig. 67; Venkataraman, G., A Systematic Account of Some South Indian Diatoms, *Proc. Indian Acad. Sci.*, Vol. 10, No. 6, Sect. B, 1939, p. 299, figs. 11, 14; Iyengar and Subrahmanyam, Fossil diatoms from Karewa Beds of Kashmir, *Proc. nat. Acad. Sci.*,

Vol. 13, Pt. 4, 1943, p. 226, figs. 1-2; Gonzalves and Gandhi, A Systematic Account of Diatoms of Bombay and Salsette—I, *J. Indian bot. Soc.*, Vol. 31, No. 3, 1952, p. 120, fig. 6; Tiffany and Britton, *Algæ of Illinois*, 1952, p. 218, pl. 58, fig. 660; Cleve-Euler, A., Die Diatomeen von Schweden und Finnland—I, *Kungl. Svenska Vetensk. Handl.*, Bd. 2, No. 1, 1951, p. 48, figs. 63 a-c (*C. meneghiniana* v. *genuina*).

Frustules rectangular in girdle view with undulate walls. Valves discoid with strong margin. Central field large and apparently smooth. Striæ thick, radial and becoming narrow towards the centre. Common.

Dimensions .. Diameter of cells 16-26 μ
Striæ 9-11 in 10 μ

Distribution .. India—Madras (Venkataraman, 1939), Kashmir (Iyengar & Subrahmanyam, 1943), Bombay (Gonzalves & Gandhi, 1952), Partabgarh (!) and Dharwar (!). Fresh-water and Brackish water.

2. *Cyclotella catenata* Brun.

(Fig. 2)

Hustedt, F., *op. cit.*, 1930, p. 108, fig. 83 b; Gonzalves and Gandhi, *op. cit.*, 1952, p. 122, fig. 9; Cleve-Euler, A., *op. cit.*, 1951, p. 47, fig. 58.

Frustules formed in chains, walls convex in the girdle view. Valves small discoid with thick margin. Central field marked with coarsely punctate, radial, long and short alternating striæ. Marginal striæ thick, radial and wedge-shaped. Rare.

Dimensions .. Diameter of cells 18-22 μ
Striæ 10-11 in 10 μ
Punctæ of the middle striæ 11-13 in 10 μ

Distribution .. India—Bombay (Gonzalves and Gandhi, 1952), and Partabgarh (!). Fresh-water.

B. Order PENNALES

I. Sub-order ARAPHIDINEÆ

1. Family FRAGILARIACEÆ

(a) Sub-family FRAGILARIOIDEÆ

Genus *Synedra* Ehrenberg, C. G. 1830

3. *Synedra nula* (Nitz.) Ehr.

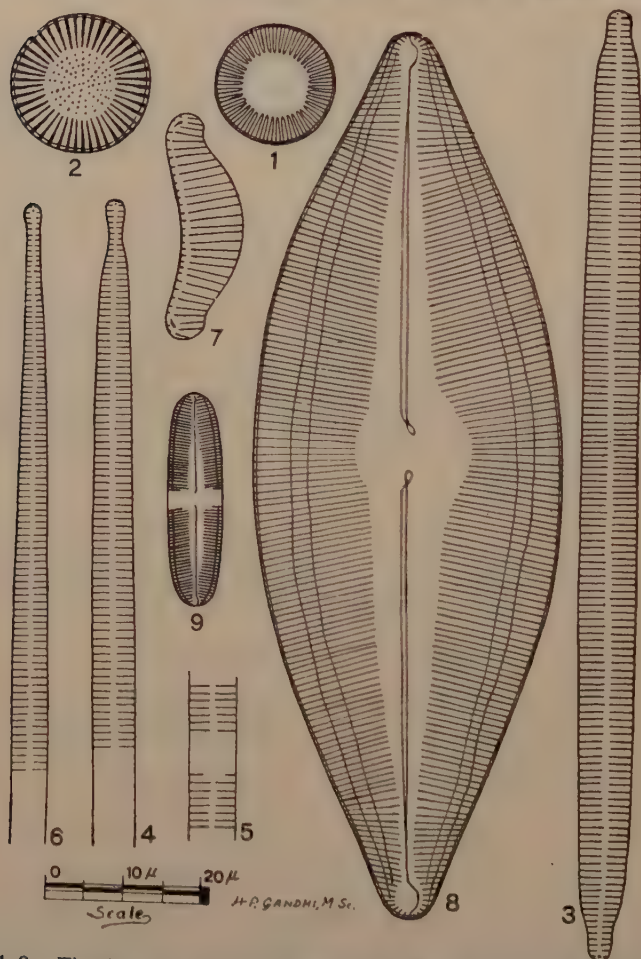
(Fig. 3)

Van Heurck, *op. cit.*, 1896, p. 310, pl. 10, fig. 409; Schönfeldt, H., *op. cit.*, 1913, p. 39, fig. 60; Hustedt, F., *op. cit.*, 1930, p. 151, fig. 159 b; Venkataraman, G., *op. cit.*, 1939, p. 305, figs. 37, 39, 43; Tiffany and Britton, *op. cit.*, 1952, p. 237, pl. 63, fig. 713; Gonzalves and Gandhi, *op. cit.*, 1952, p. 126, fig. 15.

Frustules large, in the girdle view linear with widened truncate ends. Valves linear to linear-lanceolate with constricted, produced and broadly rounded ends. Pseudoraphe narrow, linear. Central area absent. Striæ strong. Common.

Dimensions .. Length 117-145 μ
Breadth 6.8-7.5 μ
Striæ 10-11 in 10 μ

Distribution .. India—Calcutta (Ehrenberg, 1840), Assam (Biswas, 1936), Burma (West & West, 1907),



FIGS. 1-9.—Fig. 1. *Cyclotella meneghiniana* Kütz. Fig. 2. *Cyclotella catenata* Brun. Fig. 3. *Synedra ulna* (Nitz.) Ehr. Fig. 4. *Synedra ulna* (Nitz.) Ehr. var. *amphirhynchus* (Ehr.) Grun. Fig. 5. *Synedra ulna* v. *amphirhynchus*—central portion showing the central area. Fig. 6. *Synedra ulna* (Nitz.) Ehr. var. *danica* (Kütz.) Grun. Fig. 7. *Eunotia praeurupta* Ehr. var. *inflata* Grun. Fig. 8. *Caloneis permagna* (Bailey) Cleve. Fig. 9. *Caloneis bacillum* (Grun.) Mereschkowsky.

Madras (Venkataraman, 1939), Partabgarh and Kolhapur (!).

4. *Synedra ulna* (Nitz.) Ehr. var. *amphirhynchus* (Ehr.) Grun.
(Figs. 4-5)

Van Heurck, *op. cit.*, 1896, p. 311, pl. 10, fig. 414; Schönfeldt, H., *op. cit.*, 1913, p. 39; Hustedt, F., *op. cit.*, 1930, p. 154, fig. 167; Venkataraman, G., *op. cit.*, 1939, p. 308, figs. 28, 30-32; Gonzalves and Gandhi, *op. cit.*, 1952, p. 128, fig. 19.

Frustules very elongated, in the girdle view linear with widened ends. Valves linear-lanceolate with abruptly constricted, large capitate ends. Pseudoraphe narrow, linear. Central area moderate, reaching the sides. Striæ strong. Not common.

Dimensions .. Length 237-250 μ
Breadth 4.4-6 μ
Striæ 8-11 in 10 μ

Distribution .. India—Panjab (A. Majeed, 1935), Madras (Venkataraman, 1939), Bombay (Gonzalves and Gandhi, 1952), Partabgarh and Kolhapur (!). Fresh-water.

5. *Synedra ulna* (Nitz.) Ehr. var. *danica* (Kütz.) Grun.
(Fig. 6)

Van Heurck, *op. cit.*, 1896, p. 311, pl. 10, fig. 415; Schönfeldt, H., *op. cit.*, 1913, p. 39; Hustedt, F., *op. cit.*, 1930, p. 154, fig. 168; Tiffany and Britton, *op. cit.*, 1952, p. 237, pl. 63, fig. 715; Gonzalves and Gandhi, *op. cit.*, 1952, p. 127, fig. 17.

Valves elongated and slender, narrowly lanceolate with slightly capitate ends. Pseudoraphe narrow, linear. Central area present reaching the sides. Striæ delicate but distinct. Not common.

Dimensions .. Length 237-280 μ
Breadth 5-5.6 μ
Striæ 10-12 in 10 μ

Distribution .. India—Bombay (Gonzalves and Gandhi, 1952), Partabgarh and Dharwar (!). Fresh-water.

II. Sub-order RAPHIDINEÆ

1. Family EUNOTIACEÆ

(a) Sub-family EUNOTIOIDEÆ

Genus *Eunotia* Ehrenberg, C. G. 1837

6. *Eunotia prærupta* Ehr. var. *inflata* Grun.
(Fig. 7)

Van Heurck, *op. cit.*, 1896, p. 302, pl. 9, fig. 378; Hustedt, F., *op. cit.*, 1930, p. 174, fig. 212; Gonzalves and Gandhi, *op. cit.*, 1952, p. 130, fig. 25.

Frustules small and robust. Valves with highly convex dorsal and slightly concave ventral-side, ends dorsally constricted and somewhat capitate. Polar nodules clearly seen. Striæ more or less irregularly placed, coarse, interrupted by a thin but clear space (line) near the ventral side. Rather rare.

Dimensions .. Length 29–33 μ
 Breadth 8–8.4 μ
 Striæ 8–11 in 10 μ

Distribution .. India—Bombay (Gonzalves and Gandhi, 1952), Partabgarh (!). Fresh-water.

The present form agrees well with the type described by Hustedt except that ends in this form are not distinctly truncate-capitate.

III. Sub-order BIRAPHIDIOIDINEÆ

1. Family NAVICULACEÆ

(a) Sub-family NAVICULOIDEÆ

Genus **Caloneis** Cleve 1894

7. *Caloneis permagna* (Bailey) Cleve

Schönfeldt, H., *op. cit.*, 1913, p. 71, fig. 129: Hustedt, F., *op. cit.*, 1930, p. 231, fig. 349.

Navicula permagna Bailey, Van Heurck, *op. cit.*, 1896, p. 218, p. 5, fig. 202.

Frustules solitary, large and robust. Valves rhombic-lanceolate with somewhat produced, broadly rounded ends. Raphe thick and straight, central pores large, unilaterally bent; terminal fissures broadly curved and clear. Axial area moderately lanceolate; central area large, circular and somewhat unilateral. Striæ radial in the middle and convergent at the ends, crossed by two fine longitudinal lines near the margins. Rare.

Dimensions .. Length 105–150 μ
 Breadth 35.6–47 μ
 Striæ 11–13 in 10 μ

Distribution .. India—Partabgarh (!). Fresh-water.

This form agrees well with the type described and figured by Hustedt and others. It is a very beautiful form.

8. *Caloneis pulchra* Messikommer forma *partabgarhensis* f. nov.

Frustula luteis-brunis pigmentis ornata, rectangularia in aspectu zonali. Valvæ lineari-lanceolatæ, distincte in medio gibbosæ, gradatim ad apices late rotundatos tenuiores. Raphe tenuis et recta, poris centralibus distinctis et fissuris terminalibus paululum curvatis. Area axialis lineari-lanceolata; area centralis ampla et rotundata. Striæ subtiles, paululum radiales in medio sed perpendiculares ad mediam

lineam ad apices versus tenui longitudinali linea ad marginem decussatæ. Frustula $48.7-52\ \mu$ longa; $10-10.6\ \mu$ lata; striæ $18-22$ in $10\ \mu$.

Frustules with yellow-brown chromatophores, rectangular in the girdle view. Valves linear-lanceolate, prominently gibbous in the middle, gradually narrowing to broad rounded ends. Raphe thin and straight with distinct central pores and slightly curved terminal fissures. Axial area linear-lanceolate; central area large and rounded. Striæ fine, slightly radial in the middle, perpendicular to the middle line towards the ends, crossed by a fine longitudinal line near the margins. Not common.

Dimensions .. Length $48.7-52\ \mu$
Breadth $10-10.6\ \mu$
Striæ $18-22$ in $10\ \mu$

Distribution .. India—Partabgarh (!). Fresh-water.

This form resembles closely *Caloneis pulchra* Messikommer as described by Hustedt (Hustedt, *op. cit.*, 1930, p. 235, fig. 357), except that it is proportionately a larger and much broader form with a prominent gibbosity in the middle. Moreover, it differs in the outline which is somewhat linear-lanceolate and the roundish central area. It is, therefore, regarded as a new form.

9. *Caloneis clevei* (Lagerstedt) Cleve

(Fig. 11)

Hustedt, F., *op. cit.*, 1930, p. 236, fig. 359.

Valves linear-lanceolate with convex sides and slightly constricted, broadly capitate rounded ends. Raphe thin and straight with unilaterally bent central pores and large, slightly curved terminal fissures. Axial area large, linear-lanceolate; central area large, reaching the sides. Striæ radial in the middle and convergent at the ends, crossed by a fine but distinct longitudinal line close to the margins. Common.

Dimensions .. Length $46.5-54\ \mu$
Breadth $9.4-10\ \mu$
Striæ $19-21$ in $10\ \mu$

Distribution .. India—Partabgarh (!). Fresh-water.

This form also resembles *Caloneis hultenii* Petersen (Petersen, J. B., *Det. Kgl. Danske Vidensk. Selskab Biol. Meddel.*, Bd. XX, Nr. 1, 1946, p. 75, fig. 8) in the outline, but differs from it in dimensions, striæ and other details.

10. *Caloneis bacillum* (Grun.) Mereschkowsky

(Fig. 9)

Hustedt, F., *op. cit.*, 1930, p. 236, fig. 360; Tiffany and Britton, *op. cit.*, 1952, p. 248, pl. 65, fig. 748; Krishnamurthy, V., A contribution to the Diatoms flora of S. India, *J. Indian bot. Soc.*, Vol. 33, No. 4, 1954, p. 362, fig. 25.

Valves linear to linear-lanceolate with broad rounded ends. Raphe thin and straight with slightly unilaterally bent central pores. Axial area moderate, linear-lanceolate; central area wide reaching the sides. Striæ slightly radial, becoming perpendicular to the middle line towards the ends, crossed by a fine longitudinal line near the margins. Common.

Dimensions .. Length 22–27 μ
Breadth 7–7.5 μ
Striæ 25–28 in 10 μ

Distribution .. India—Madras (Krishnamurthy, 1954) and Partabgarh (!). Fresh-water.

11. *Caloneis silicula* (Ehr.) Cleve

(Fig. 35)

Schönfeldt, H., *op. cit.*, 1913, p. 72, fig. 132; Hustedt, F., *op. cit.*, 1930, p. 236, fig. 362; Tiffany and Britton, *op. cit.*, 1952, p. 248, pl. 65, fig. 743.

Valves linear to linear-lanceolate with triundulate margins and broadly wedge-shaped ends. Raphe thin and straight with slightly curved terminal fissures. Axial area moderate, linear-lanceolate; central area large. Striæ slightly radial throughout, crossed by a fine longitudinal line near the margins. Fairly common.

Dimensions .. Length 32.5–54 μ
Breadth 6–7 μ
Striæ 18–22 in 10 μ

Distribution .. India—Bombay and Partabgarh (!). Fresh-water.

Genus *Neidium* Pfitzer 1871

12. *Neidium bisulcatum* (Lagerstedt) Cleve

(Fig. 12)

Schönfeldt, H., *op. cit.*, 1913, p. 74, fig. 134; Hustedt, F., *op. cit.*, 1930, p. 242, fig. 374; Krishnamurthy, V., *op. cit.*, 1954, p. 363, fig. 34.

Valves linear with almost parallel sides and broad rounded ends. Raphe thin and straight with central pores bent in the opposite directions and terminal fissures bifurcated. Axial area narrow, slightly widened between the middle and the ends; central area large, roundish or transversely elliptical. Striæ fine but distinctly punctate, radial in the middle, perpendicular to the middle line in between and convergent at the ends, crossed by a hyaline furrow near the margins. Rare.

Dimensions .. Length 25.6–40.5 μ
Breadth 7.5–9 μ
Striæ 25–30 in 10 μ

Distribution .. India—Madras (Krishnamurthy, 1954) and Partabgarh (!). Himalaya? (*Navicula bisulcata*, Dickie, 1882). Fresh-water.

13. *Neidium bisulcatum* (Lagerstedt) Cleve f. *undulata* O. Müll.

(Fig. 13)

Schönfeldt, H., *op. cit.*, 1913, p. 74; Hustedt, F., *op. cit.*, 1930, p. 242, fig. 375; Gonzalves and Gandhi, *Syst. Acc. Diat.*, etc.—II, *J. Indian bot. Soc.*, Vol. 32, No. 4, 1953, p. 248, fig. 77.

Valves linear with triundulate sides and subcuneate ends. Raphe thin and straight with central pores bent in the opposite directions and terminal fissures bifurcated. Axial and central areas as in the type. Striæ fine but distinctly punctate, radial in the middle, perpendicular to the middle line in between and convergent at the ends, crossed by a hyaline furrow near the margins. Not common.

Dimensions .. Length 45–60 μ
 Breadth 7.5–8 μ
 Striæ 28–30 in 10 μ

Distribution .. India—Bombay (Gonzalves and Gandhi 1953) and Partabgarh (!). Fresh-water.

Genus **Stauroneis** Ehrenberg 1843

14. *Stauroneis partabgarhensis* sp. nov.

(Fig. 14)

Frustula solitaria, libere natantia, in aspectu zonali rectangularia, septis polaris nullis. Valves late-lanceolatae, utroque apice constricto et aliquantum elongato ac capitato. Raphe crassa, ornata poris centralibus paullum unilateraliter inclinatis atque fissuris terminalibus curvatis. Area axialis modica, linearis vel inter polos et centrum dilatata; area centralis staurodea rectangularis versus latera dilatata. Striæ radiales, tenues sed distincte punctatae. Frustula 61–65 μ longa; 16–18 μ lata; striæ 19–21 in 10 μ .

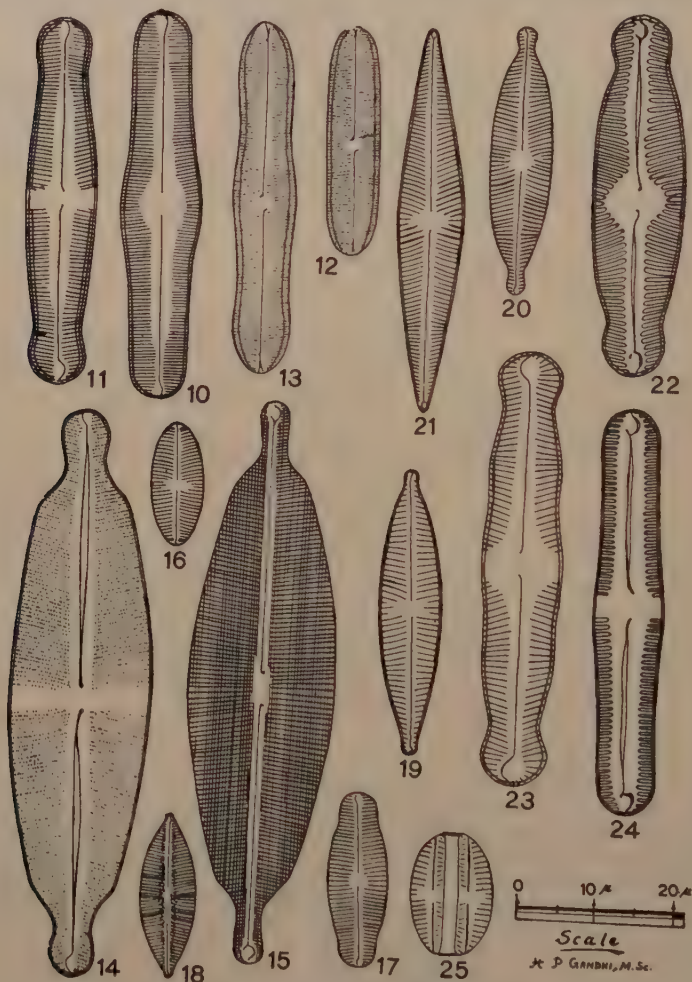
Frustules solitary, free-floating, rectangular in the girdle, view without polar septa. Valves broadly lanceolate with abruptly constricted, somewhat produced capitate ends. Raphe thick with slightly unilaterally bent central pores and curved terminal fissures. Axial area moderate, linear or slightly widened between the middle and ends; central area a rectangular stauros, somewhat widened towards the margins. Striæ radial, fine but distinctly punctate. Rather rare.

Dimensions .. Length 61–65 μ
 Breadth 16–18 μ
 Striæ 19–21 in 10 μ

Distribution .. India—Partabgarh. Fresh-water.

This form remotely resembles *Stauroneis alabamæ* Heiden var. *angulata* Heiden as described and figured by Hustedt (Hustedt, *op. cit.*, 1930, p. 258, fig. 413). in the outline and raphe, but the stauros and striæ in this form are not at all characteristic of *Stauroneis alabamæ* or its var. *angulata*, hence it differs. It also differs from *S. phylloides* Ehr., described and figured by Tiffany and Britton (Tiffany and Britton,

op. cit., 1952, p. 266, pl. 71, fig. 821), in having distinctly capitate ends, less radial striæ and broad rectangular stauros which slightly widens near the margins. It further differs from *S. phænicenteron* (Nitz.) Ehr. var. *amphilepta* (Ehr.) Cleve (Tiffany and Britton, 1952, p. 266, pl. 71,



FIGS. 10-25.—Fig. 10. *Caloneis pulchra* Messikommer forma *partabgarhensis* f. nov. Fig. 11. *Caloneis clevei* (Lagerstedt) Cleve. Fig. 12. *Neidium bisulcatum* (Lagerstedt) Cleve. Fig. 13. *Neidium bisulcatum* (Lagerstedt) Cleve f. *undulata* O. Müll. Fig. 14. *Stauroneis partabgarhensis* sp. nov. Fig. 15. *Navicula cuspidata* Kütz. var. *ambigua* (Ehr.) Cleve. Fig. 16. *Navicula pupula* Kütz. var. *elliptica* Hustedt. Fig. 17. *Navicula protracta* Grun. Fig. 18. *Navicula krasskei* Hustedt. Fig. 19. *Navicula cryptocephala* Kütz. Fig. 20. *Navicula partabgarhensis* sp. nov. Fig. 21. *Navicula radiosa* Kutz. var. *tenella* (Bréb.) Grun. Fig. 22. *Pinnularia gibba* Ehr. var. *mesogongyla* (Ehr.) Hustedt. Fig. 23. *Pinnularia gibba* Ehr. f. *subundulata* Mayer. Fig. 24. *Pinnularia brevicostata* Cleve. Fig. 25. *Amphora ovalis* Kütz. var. *pediculus* Kütz.

fig. 826), in not having broadly rostrate, but distinctly capitate ends. Moreover, the striae are more closely set and fine but distinctly punctate. It does not resemble any other known forms, hence it is regarded as a new species.

Genus **Navicula** Bory, 1822

Section *Naviculæ orthostichæ* Cleve

15. *Navicula cuspidata* Kütz. var. *ambigua* (Ehr.) Cleve

(Fig. 15)

Schönfeldt, H., *op. cit.*, 1913, p. 76; Hustedt, F., *op. cit.*, 1930, p. 268, fig. 434; Venkataraman, G., *op. cit.*, 1939, p. 327, fig. 94; Tiffany and Britton, *op. cit.*, 1952, p. 254, pl. 68, fig. 790; Cleve-Euler, A., *Diat. Schweden u. Finnland, Kungl. Svenska Vetens. Handl.*, Pt. V, Bd. 3, No. 3, 1952, p. 18, fig. 1353 d.

N. ambigua (Ehr.) Cl.—Van Heurck, *op. cit.*, 1896, p. 214, pl. 4, fig. 192.

Frustules solitary, in the girdle view rectangular. Valves rhombic-lanceolate with abruptly narrowed, constricted, much produced capitate ends. Raphe thin and straight with hook-like central pores. Axial area narrow, linear, slightly widened in the middle due to interruption of longitudinal striae. Striae radial, punctate; longitudinal striae finer and more closely set than the transverse ones. Craticular plates were seen in some of the forms. Not common.

Dimensions .. Length 72·8–80 μ
Breadth 19–21 μ
Trans. striae 17–20 in 10 μ
Long. striae 23–26 in 10 μ

Distribution .. India—Madras (Venkataraman, 1939), Bombay, Dharwar, Mugud, Kolhapur, and Partabgarh (!). Fresh-water.

Section *Naviculæ bacillares* Cleve

16. *Navicula pupula* Kütz. var. *capitata* Hust.

(Fig. 46)

Hustedt, F., *op. cit.*, 1930, p. 281, fig. 467 c.

Valves linear with slightly convex sides and constricted, broadly capitate rounded ends. Raphe thin and straight. Axial area narrow and linear; central area transversely rectangular and large; terminal nodules distinct. Striae radial and curved, long and short striae alternate in the middle. Not common.

Dimensions .. Length 27–30 μ
Breadth 7·7 μ
Striae 22–24 in 10 μ

Distribution .. India—Bombay and Partabgarh (!). Fresh-water.

17. *Navicula pupula* Kütz. var. *elliptica* Hust.

(Fig. 16)

Schönfeldt, H., *op. cit.*, 1913, p. 79; Hustedt, F., *op. cit.*, 1930, p. 282, fig. 467 d.

Valves broadly elliptic-lanceolate with rounded ends. Raphe thin and straight. Axial area narrow, linear; central area rectangular, large; polar nodules distinct. Striæ fine, radial and curved; long and short striæ alternate in the middle. Common.

Dimensions .. Length 16–18 μ
Breadth 6·8–7 μ
Striæ 16–18 in 10 μ

Distribution .. India—Bombay and Partabgarh (!). Fresh-water.

Section *Naviculæ decipientes* Cleve18. *Navicula protracta* Grun.

(Fig. 17)

Hustedt, F., *op. cit.*, 1930, p. 284, fig. 472; Venkataraman, G., *op. cit.*, 1939, p. 328, fig. 93; Tiffany and Britton, *op. cit.*, 1952, p. 254, pl. 67, fig. 775.

Valves linear or slightly linear-elliptical with constricted, broadly rostrate, subtruncate ends. Raphe thin and straight with slightly curved terminal fissures. Axial area very narrow, linear; central area small, rounded. Striæ strong, radial, indistinctly punctate, distantly placed in the middle, closely set and parallel at the ends. Not common.

Dimensions .. Length 16–27·5 μ
Breadth 6–8·8 μ
Striæ 16–22 in 10 μ

Distribution .. India—Madras (Venkataraman, 1939), Bombay Partabgarh (!). Fresh-water.

19. *Navicula fluens* Hust.

(Fig. 47)

Hustedt, F., *op. cit.*, 1930, p. 285, fig. 474.

Valves elliptic-lanceolate with broad rounded ends. Raphe thin and straight. Axial area very narrow, linear; central area scarcely formed. Striæ slightly radial throughout, somewhat distantly placed in the middle. Fairly common.

Dimensions .. Length 11–16 μ
Breadth 5–6 μ
Striæ 30–32 in 10 μ

Distribution .. India—Partabgarh (!). Fresh-water.

This form agrees well with the type described and figured by Hustedt.

Section *Naviculæ minusculæ* Cleve20. *Navicula krasskei* Hust.

(Fig. 18)

Hustedt, F., *op. cit.*, 1930, p. 287, fig. 481.

Valves broadly lanceolate with constricted, slightly produced acute ends. Raphe thin and straight with indistinct terminal fissures. Axial area very narrow, linear with longitudinal depressions; central area scarcely formed. Striæ radial throughout, very fine and indistinct. Very common.

Dimensions .. Length 13–22 μ
 Breadth 6–8.7 μ
 Striæ about 30 in 10 μ

Distribution .. India—Partabgarh (!). Fresh-water.

This form agrees well with the type described and figured by Hustedt, and also the longitudinal depressions in the axial area are noted. Some larger forms also are recorded from this region.

21. *Navicula vitrea* (Østrup) Hust.

(Fig. 48)

Hustedt, F., *op. cit.*, 1930, p. 289, fig. 489.

Valves small, linear-lanceolate with parallel sides in the middle; ends narrowed, broadly wedge-shaped and rounded. Raphe thin and straight. Axial area very narrow, linear; central area only slightly developed. Striæ radial throughout, crossed by a very thin hyaline line close to the margins. Not common.

Dimensions .. Length 15–22 μ
 Breadth 6–7 μ
 Striæ 30 in 10 μ

Distribution .. India—Partabgarh (!). Fresh-water.

This form agrees well with the type described and figured by Hustedt, except that some smaller forms were also observed.

Section *Naviculæ lineolatæ* Cleve22. *Navicula cryptocephala* Kütz.

(Fig. 19)

Van Heurck, *op. cit.*, 1896, p. 180, pl. 3, fig. 122; Schönfeldt, H., *op. cit.*, 1913, p. 92, fig. 189; Hustedt, F., *op. cit.*, 1930, p. 295, fig. 496; Tiffany and Britton, *op. cit.*, 1952, p. 255, pl. 67, fig. 767.

Valves lanceolate with constricted, more or less produced capitate ends. Raphe thin and straight with distinct central pores and slightly curved terminal fissures. Axial area narrow, linear; central area moderate and squarish. Striæ finely lineate, radial in the middle and convergent at the ends; long and short striæ alternate in the middle. Not common.

- Dimensions* . . Length 30–37.5 μ
 Breadth 6.6–8 μ
 Striæ 14–16 in 10 μ
- Distribution* . . India—Himalaya (Dickie, 1882), Burma (West & West, 1907), Calcutta (Skvortzow, 1935), Bombay (Gonzalves and Gandhi), Kolhapur and Partabgarh (!). Fresh-water.

This form resembles very closely the type described by Hustedt and others, except that it is somewhat a broader form and has fewer striæ.

23. *Navicula partabgarhensis* sp. nov.

(Fig. 20)

Valvæ lineares-ellipticæ, utroque apice abrupte constricto et distincte rotundato ac capitato. Raphe tenuis et recta, fissuris terminalibus paululum curvatis. Area axialis angusta, linearis; area centralis lata ac rotundata. Striæ lineatæ, radiales et in medio curvatæ, in utroque apice convergentes. Frustule 35–38 μ longa; 7.5–8.2 μ lata; striæ 18–20 in 10 μ .

Valves linear-elliptical with abruptly constricted and distinctly capitate rounded ends. Raphe thin and straight with slightly curved terminal fissures. Axial area narrow, linear; central area large, roundish. Striæ lineate, radial and curved in the middle, convergent at the ends. Rather rare.

- Dimensions* . . Length 35–38 μ
 Breadth 7.5–8.2 μ
 Striæ 18–20 in 10 μ

Distribution . . India—Partabgarh (!). Fresh-water.

This form can satisfactorily be placed in the Section—*Navicula lineolata* Cleve, on account of its striæ being lineate, radial in the middle and convergent at the ends. Further, this form remotely resembles *Navicula exigua* (Greg.) O. Müll. (Hustedt, *op. cit.*, 1930, p. 305, fig. 538) in the outline, but as striæ are not radial throughout and long and short striæ do not alternate in the middle, it thus differs. It does not agree with or come near to any other known forms, hence it is regarded as a new species.

24. *Navicula cari* Ehr.

(Fig. 49)

Hustedt, F., *op. cit.*, 1930, p. 299, fig. 512.

Valves narrowly lanceolate with almost acute rounded ends. Raphe thin and straight with curved terminal fissures. Axial area narrow, linear; central area large, obliquely rectangular. Striæ radial in the middle, at the ends convergent and somewhat closely placed. Fairly common.

Dimensions .. Length 24–33.3 μ
 Breadth 5–6.5 μ
 Striæ 14–18 in 10 μ

Distribution .. India—Bombay and Partabgarh (!). Fresh-water.

This form agrees well with Hustedt's type except that it is somewhat smaller and slender form.

25. *Navicula radiosa* Kütz. var. *tenella* (Bréb.) Grun.

(Fig. 21)

Van Heurck, *op. cit.*, 1896, p. 180, pl. 3, fig. 114; Schönfeldt, H., *op. cit.*, 1913, p. 95; Hustedt, F., *op. cit.*, 1930, p. 299; Tiffany and Britton, *op. cit.*, 1952, p. 255, pl. 67, fig. 781.

Valves narrowly lanceolate and gradually tapering to acute rounded ends. Raphe thin and straight with distinct terminal fissures. Axial area narrow, linear; central area large, obliquely rectangular. Striæ radial in the middle and convergent at the ends. Not common.

Dimensions .. Length 45–50 μ
 Breadth 8–8.7 μ
 Striæ 14–18 in 10 μ

Distribution .. India—[Ceylon (Skvortzow, 1932)], and Partabgarh (!). Fresh-water.

This form is slightly broader than Hustedt's form (breadth 5–6 μ), but agrees well in other respects. Van Heurck does not give the dimensions of his form, but states that the striæ are finer and approximate (15–18 in 10 μ). Schönfeldt states that this form is smaller than the type with a fewer striæ.

26. *Navicula vanhæffeniformis* sp. nov.

(Fig. 50)

Valvæ parvæ, lineares, marginibus parallelis ac cuneatis-acutis in utroque apice. Raphe tenuis et recta atque fissuris terminalibus anguste curvatis. Area axialis angusta, linearis; area centralis paullum dilatata. Striæ ubique radiales, indistincte lineatæ, paullum distanter in medio positæ. Frustula 16.7–25.5 μ longa; 4–6 μ lata; striæ 13–16 in 10 μ .

Valves small, linear with parallel sides and wedge-shaped acute ends. Raphe thin and straight with narrow, curved terminal fissures. Axial area narrow, linear; central area slightly dilated. Striæ throughout radial, indistinctly lineate, slightly distantly placed in the middle. Not common.

Dimensions .. Length 16.7–25.5 μ
 Breadth 4–6 μ
 Striæ 13–16 in 10 μ

Distribution .. India—Partabgarh (!). Fresh-water.

This form strongly resembles *Navicula vanhoeffeni* Grun., in the outline and cuneate ends, as figured by Cleve-Euler (Cleve-Euler, *op. cit.*, 1952, p. 25, fig. 1379), but differs very much in the dimensions, absence of stauros, habitat and other details. And as the author has not given any information regarding the striæ both in the text and the figure, I am unable to refer my form to *N. vanhoeffeni*. It also resembles *N. natchikæ* Petersen (Petersen, J. B., *Algæ collected by etc.*, . . . , *Det Kgl. Dansk Viden. Sels. Biol. Meddel.*, Bd. XX, Nr. 1, 1946, p. 92, fig. 15) somewhat in the outline and radial striæ, but as this form is rather slender and has sharply defined cuneate ends and indistinctly lineate striæ, it differs from it (*N. natchikæ*). It again, except for the outline, differs from *N. gracilis* A. Mayer (Hustedt, F., *op. cit.*, 1930, p. 299, fig. 514), in having smaller size, distinctly radial, closely set and indistinctly lineate striæ. Further, it does not agree with any other known forms, hence it is regarded as a new species.

27. *Navicula gonzalvesiana* sp. nov.

(Fig. 51)

Valvæ parvæ, late-lanceolatæ, apicibus acutis rotundatis. Raphe paullum crassa et recta atque fissuris terminalibus latis ac curvatis. Area axialis angusta, linearis; area centralis parva atque elliptica. Striæ fortes, lineatæ, ubique radiales, distincte in utroque apice geniculatæ. Frustula 28–32 μ longa; 7·8–8·4 μ lata; Striæ 12–14 in 10 μ .

Valves small, broadly lanceolate with acute rounded ends. Raphe slightly thick and straight with large, curved terminal fissures. Axial area narrow, linear; central area small, elliptical. Striæ strong, lineate, throughout radial, at the ends distinctly geniculate. Not common.

Dimensions . . Length 28–32 μ
 Breadth 7·8–8·4 μ
 Striæ 12–14 in 10 μ

Distribution . . India—Partabgarh (!). Fresh-water.

This form, except for the geniculate striæ at the ends, differs from *N. oblonga* Kütz. (Hustedt, *op. cit.*, 1930, p. 307, fig. 550), in the outline, dimensions and the number of striæ. It also differs from *N. opima* Grun. (Van Heurck, *op. cit.*, 1896, p. 184, pl. 25, fig. 714) in several features but for the outline. Moreover, the striæ are not being described as geniculate in the text though they appear to be so in the figure, hence it cannot be ascribed to *N. opima* with any certainty. However it is a distinctive form, hence it is regarded as a new species and named in honour of my esteemed Prof. (Mrs.) E. A. Gonzalves.

Genus **Pinnularia** Ehrenberg 1840

Section **Divergentes** Cleve

28. *Pinnularia microstauron* (Ehr.) Cleve

(Fig. 52)

Schönfeldt, H., *op. cit.*, 1913, p. 103, fig. 220; Hustedt, F., *op. cit.*, 1930, p. 320, fig. 582.

Frustules solitary, rectangular in the girdle view. Valves linear-lanceolate with constricted, produced or somewhat capitate ends. Raphe thin and slightly undulate; central pores unilaterally bent and terminal fissures slightly curved. Axial area moderate, lanceolate; central area large, reaching the sides. Striæ strong, radial in the middle and convergent at the ends. Not common.

Dimensions .. Length 45–54 μ
Breadth 10·6–11 μ
Striæ 12–14 in 10 μ

Distribution .. India (Ceylon—Skvortzow, 1932), Bombay, Mugud and Partabgarh (!). Fresh-water.

Section *Tabellariæ* Cleve

29. *Pinnularia gibba* Ehr. f. *subundulata* Mayer

(Fig. 23)

Hustedt, F., *op. cit.*, 1930, p. 327, fig. 601; Venkataraman, G., *op. cit.*, 1939, p. 338, fig. 108.

Valves linear to linear-lanceolate with slightly undulate margins and constricted, broadly capitate rounded ends. Raphe thin and straight with very closely placed central pores slightly unilaterally bent, terminal fissures curved. Axial area broad, linear; central area very wide reaching the sides. Striæ strong, radial in the middle and strongly convergent at the ends. Rare.

Dimensions .. Length 56–70 μ .
Breadth 11–12 μ
Striæ in the middle 10–12 in 10 μ
Striæ at the ends 12–14 in 10 μ

Distribution .. India—Madras (Venkataraman, 1939) and Partabgarh (!). Fresh-water.

30. *Pinnularia gibba* Ehr. var. *mesogongyla* (Ehr.) Hust.

(Fig. 22)

Hustedt, F., *op. cit.*, 1930, p. 327, fig. 602.

Frustules solitary and robust, rectangular in the girdle view. Valves linear-lanceolate with convex sides in the middle; ends constricted, capitate rounded. Raphe thick, slightly undulate with distinct unilaterally bent central pores and short terminal fissures. Axial area moderate, linear; central area very large, rounded, almost reaching the sides. Striæ strong and thick, radial in the middle and strongly convergent at the ends. Rare.

Dimensions .. Length 37–50 μ
Breadth 11·8–12·5 μ
Striæ 9–10 in 10 μ

Distribution .. India—Bombay and Partabgarh (!). Fresh-water.

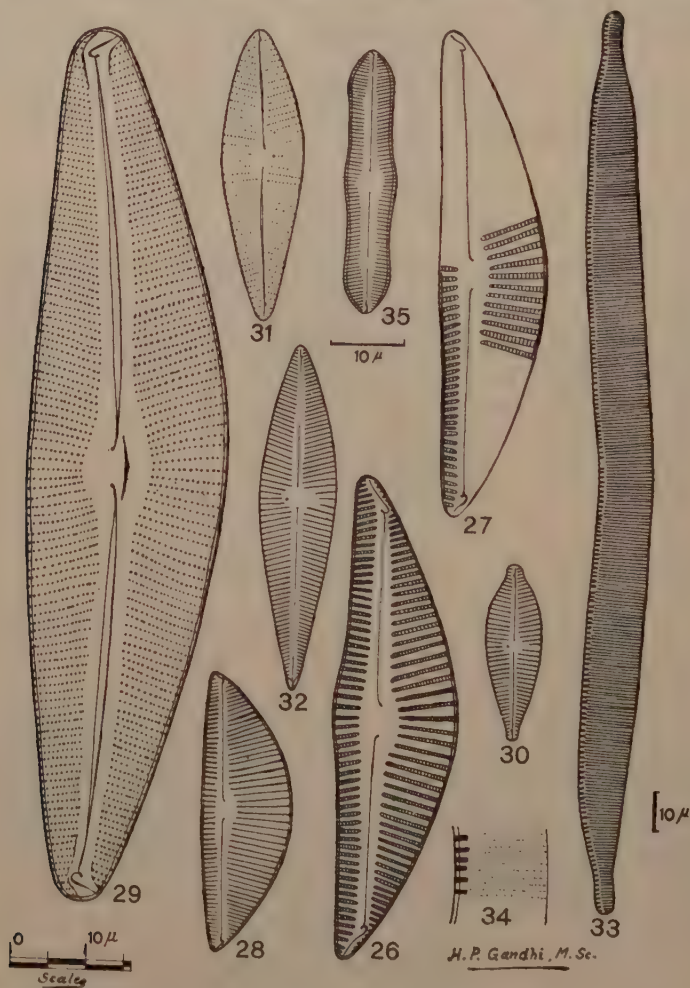
This form agrees well with the type described and figured by Hustedt.

Section *Brevistrietae* Cleve31. *Pinnularia brevicostata* Cleve

(Fig. 24)

Schönfeldt, H., *op. cit.*, 1913, p. 107, fig. 230; Hustedt, F., *op. cit.*, 1930, p. 329, fig. 609.

Frustules solitary, rectangular in the girdle view. Valves linear with almost parallel sides or slightly gibbous in the middle; ends



FIGS. 26-35.—Figs. 26-27. *Cymbella turgida* (Greg.) Cleve. Fig. 28. *Cymbella ventricosa* Kütz. Fig. 29. *Cymbella aspera* (Ehr.) Cleve. Fig. 30. *Gomphonema parvulum* (Kütz.) Grun. Fig. 31. *Gomphonema lanceolatum* Ehr. var. *insignis* (Greg.) Cleve. Fig. 32. *Gomphonema gracile* Ehr. Fig. 33. *Hantzschia elongata* (Hantzsch) Grun. Fig. 34. *Hantzschia elongata*—under higher magnification, showing the punctate striæ. Fig. 35. *Caloneis silicula* (Ehr.) Cleve.

broadly rounded. Raphe thick, but simple, slightly undulate on the strongly marked side; central pores unilaterally bent and terminal fissures large comma-shaped. Axial area broad, linear-lanceolate, $\frac{1}{4}$ – $\frac{1}{2}$ the breadth of the valve; central area large reaching the sides. Striæ strong and thick, scarcely radial, throughout parallel. Rather rare.

Dimensions .. Length 47·5–50 μ
 Breadth 9·3–10 μ
 Striæ 8–10 in 10 μ

Distribution .. India—Partabgarh (!). Fresh-water.

This form resembles very closely the type described and figured by Hustedt, except that it is a smaller form.

(b) *Sub-family* GOMPHOCYMBELLOIDEÆ

Genus **Amphora** Ehrenberg 1840

32. *Amphora ovalis* Kütz. var. *pediculus* Kütz.

(Fig. 25)

Van Heurck, *op. cit.*, 1896, p. 127, pl. 1, fig. 19; Schönfeldt, H., *op. cit.*, 1913, p. 142; Hustedt, F., *op. cit.*, 1930, p. 343, fig. 629.

Frustules small to very small, broadly elliptical with truncate-rounded ends in the girdle view. Valves lunate with highly convex dorsal—and straight or slightly concave ventral-side, ends broad, rounded. Raphe thin and slightly arcuate. Axial area narrow; central area very large, reaching the ventral side and almost the dorsal side. Striæ radial, punctate, convergent at the ends on the ventral side. Common.

Dimensions .. Length 10–17 μ
 Breadth 8–10·6 μ
 Striæ 10–12 in 10 μ

Distribution .. India—Bombay and Partabgarh (!). Fresh-water.

Genus **Cymbella** Agardh 1830

33. *Cymbella rupicola* Grun.

(Fig. 40)

Schönfeldt, H., *op. cit.*, 1913, p. 131, fig. 282; Hustedt, F., *op. cit.*, 1930, p. 353, fig. 655.

Valves slightly asymmetrical, lanceolate with strongly convex dorsal and slightly convex ventral-side; ends somewhat acute, constricted and produced. Raphe thin, very slightly excentric, arcuate with central pores ventrally bent. Axial area very narrow and slightly widened in the centre. Striæ radial throughout, closely set at the ends and on the ventral side. Fairly common.

Dimensions .. Length 22·4–30 μ
 Breadth 9–10 μ
 Striæ on the dorsal side 12–13 in 10 μ . Striæ
 at the ends and on the ventral side 15–16 in
 10 μ .

Distribution .. India—Partabgarh (!). Fresh-water.

This form agrees well with Hustedt's type.

34. *Cymbella turgida* (Greg.) Cleve

(Figs. 26–27)

Schönfeldt, H., *op. cit.*, 1913, p. 138, fig. 302; Hustedt, F., *op. cit.*, 1930, p. 358, fig. 660; Venkataraman, G., *op. cit.*, 1939, p. 343., fig. 125; Voigt, M., Note sur Quelques Espèces Chinoises du Genre *Cymbella*, Musée Heude *Notes de Botanique Chinoise*, No. 5, 1943, p. 34, pl. II, fig. 14; Tiffany and Britton, *op. cit.*, 1952, p. 279, pl. 74, fig. 862.

Encyonema turgidum (Greg.) Cl.—Van Heurck, *op. cit.*, 1896, p. 149, pl. 1, fig. 45.

Valves lunate with strongly convex dorsal- and almost straight or often centrally gibbous ventral-side; ends more or less acute, rounded. Raphe strongly excentric, straight with central pores dorsally bent and the terminal fissures ventrally directed. Axial area moderate, linear; central area small, ellipsoidal. Striæ strong, distinctly lineate, radial and distantly placed in the middle; convergent at the ends on the ventral side. Common.

Dimensions .. Length 48–60·6 μ
 Breadth 11–15·6 μ
 Striæ in the middle 7–9 in 10 μ
 Striæ at the ends 10–12 in 10 μ .

Distribution .. India—Madras (Venkataraman, 1939), Bombay, Dharwar, Mugud, Kolhapur and Partabgarh (!). Fresh-water.

35. *Cymbella ventricosa* Kütz.

(Fig. 28)

Schönfeldt, H., *op. cit.*, 1913, p. 139, fig. 308; Hustedt, F., *op. cit.*, 1930, p. 359, fig. 661; Voigt, M., *op. cit.*, 1943, p. 35; Tiffany and Britton, *op. cit.*, 1952, p. 279, pl. 74, fig. 871.

Encyonema ventricosum Kütz.—Van Heurck, *op. cit.*, 1896, p. 150, pl. 1, fig. 49.

Valves lunate to half-elliptical with highly convex dorsal- and almost straight to slightly convex ventral-side; ends acutely rounded. Raphe thin and straight, strongly excentric with dorsally bent central pores and ventrally directed terminal fissures. Axial area narrow, linear-lanceolate; central area small. Striæ finely punctate, radial,

distantly placed in the middle, at the ends convergent only on the ventral side.

Dimensions .. Length 35–47 μ
 Breadth 11–12 μ
 Striæ in the middle 10–11 in 10 μ
 Striæ at the ends 13–17 in 10 μ

Distribution .. India—(Afghanistan—Schaarschmidt, 1886), Madras (Krishnamurthy, 1954); (Burma—“*Cocconema ventricosum*” West & West, 1907), Calcutta (Biswas, 1937), Bombay, Kolhapur, Dharwar and Partabgarh (!). Fresh-water.

36. *Cymbella aspera* (Ehr.) Cleve

(Fig. 29)

Schönfeldt, H., *op. cit.*, 1913, p. 138, fig. 301; Hustedt, F., *op. cit.*, 1930, p. 365, fig. 680; Iyengar and Subrahmanyam, *op. cit.*, 1943, p. 232, figs. 25–26; Voigt, M., *op. cit.*, 1943, p. 7; Tiffany and Britton, *op. cit.*, 1952, p. 279, pl. 73, fig. 858.

Cymbella gastroides Kütz.—Van Heurck, *op. cit.*, 1896, p. 146, pl. 1, fig. 35.

Frustules large and robust, found in gelatinous masses. Valves asymmetrical, semi-lanceolate with strongly convex dorsal- and straight or slightly convex or swollen ventral-side; ends obtusely rounded. Raphe thick, arcuate, slightly excentric with large, ventrally bent central pores and dorsally directed terminal fissures. Axial area moderate, linear; central area slightly formed, rounded with an arcuate marking on the dorsal side. Striæ radial in the middle and somewhat perpendicular to the middle line towards the ends, clear and coarsely punctate. Common and variable form.

Dimensions .. Length 102–144 μ
 Breadth 25–31 μ
 Striæ in the middle 7–9 in 10 μ
 Striæ at the ends 9–11 in 10 μ
 Punctæ 14–18 in 10 μ

Distribution .. India—Kashmir (Iyengar & Subrahmanyam 1943), Bombay, Dharwar, Kolhapur and Partabgarh (!). Fresh-water.

This form agrees well with the type described and figured by Hustedt and others, except that it is somewhat convex on the ventral side.

Genus *Gomphonema* Agardh 1824

37. *Gomphonema parvulum* (Kütz.) Grun.

(Fig. 30)

Van Heurck, *op. cit.*, 1896, p. 272, pl. 7, fig. 306; Schönfeldt, *op. cit.*, 1913, p. 124, fig. 270; Hustedt, F., *op. cit.*, 1930, p. 372,

fig. 713 a; Venkataraman, G., *op. cit.*, 1939, p. 345, fig. 121; Tiffany and Britton, *op. cit.*, 1952, p. 272, pl. 72, fig. 838.

Valves lanceolate-clavate with short, constricted, produced, rounded ends. Raphe thin and straight. Axial area very narrow; central area unilateral with an isolated stigma on the opposite side. Striæ radial, indistinctly punctate, shortened opposite the stigma. Not common.

Dimensions .. Length 23–27 μ
Breadth 6.8 μ
Striæ 13–16 in 10 μ

Distribution .. India—Calcutta (Skvortzow, 1935), Madras (Venkataraman, 1939), Bombay, Kolhapur, and Partabgarh (!). Fresh-water.

38. *Gomphonema lanceolatum* Ehr. var. *insignis* (Greg.) Cleve

(Fig. 31)

Hustedt, F., *op. cit.*, 1930, p. 376, fig. 701; Venkataraman, G., *op. cit.*, 1939, p. 348, fig. 118.

Valves broadly lanceolate-clavate with acute ends. Raphe thick with unilaterally bent central pores and distinct terminal fissures. Axial area moderate, linear; central area unilateral with an isolated stigma on the opposite side. Striæ radial, fine but distinctly punctate, in the centre shortened. Not common.

Dimensions .. Length 38–45 μ
Breadth 10.6 μ
Striæ 9–11 in 10 μ

Distribution .. India—Madras (Venkataraman, 1939), Bombay, Dharwar, Mugud and Partabgarh (!). Fresh-water.

39. *Gomphonema gracile* Ehr.

(Fig. 32)

Van Heurck, *op. cit.*, 1896, p. 272, pl. 7, fig. 309; Schönfeldt, H., *op. cit.*, 1913, p. 121, fig. 264; Hustedt, F., *op. cit.*, 1930, p. 376, fig. 702; Krishnamurthy, V., *op. cit.*, 1954, p. 374, fig. 53.

Valves lanceolate-clavate, strongly narrowed from the middle towards the ends which are acute. Raphe thin and straight. Axial area narrow, linear; central area small, rounded, slightly unilateral with an isolated stigma on the opposite side. Striæ radial throughout, more closely set towards the extremities, indistinctly punctate. Rather rare.

Dimensions .. Length 43–50 μ
Breadth 9.3–10 μ
Striæ 12–17 in 10 μ

Distribution .. India—(Afghanistan—Schaarschmidt, 1886), (Ceylon—Skvortzow, 1932; West & West, 1902), Madras (Krishnamurthy, 1954), Calcutta (Ehrenberg, 1845), Dharwar, Kolhapur, Bombay and Partabgarh (!). Fresh-water.

2. Family *NITZSCHIACEÆ*

(a) Sub-family *NITZSCHIOIDEÆ*

Genus *Hantzschia* Grunow 1880

40. *Hantzschia elongata* (Hantz.) Grun.

(Figs. 33, 34)

Hustedt, F., *op. cit.*, 1930, p. 395, fig. 751; Cleve-Euler, A., *op. cit.*, 1952, p. 51, fig. 1421 g, h.

H. amphioxys var. *elongata* Grun.—Van Heurck, *op. cit.*, 1896, p. 381, pl. 15, fig. 487 b.

Frustules elongated, generally free, linear in the girdle view. Valves slender, linear with parallel sides, distinctly bent in the middle with constricted, narrowed and produced, backwardly bent subcapitate ends. Keel excentric, keel punctæ small, distantly placed in the middle. Striæ fine and indistinctly punctate. Rare.

Dimensions .. Length 195–227 μ
 Breadth 13·8 μ
 Keel punctæ 8–10 in 10 μ
 Striæ 13–16 in 10 μ

Distribution .. India—Bombay and Partabgarh (!). Fresh-water.

This form agrees well with the type described and figured by Hustedt and others, except that it is a little smaller form.

Genus *Nitzschia* Hassall 1845

Section *Tryblionellæ* (W. Smith, Grunow) Hustedt, etc.

41. *Nitzschia tryblionella* Hantz. var. *levidensis* (W. Smith) Grun.

(Fig. 36)

Van Heurck, *op. cit.*, 1896, p. 385, pl. 15, fig. 494; Schönfeldt, H., *op. cit.*, 1913, p. 151; Hustedt, F., *op. cit.*, 1930, p. 399, fig. 760; Venkataraman, G., *op. cit.*, 1939, p. 352, fig. 141; Cleve-Euler, A., *op. cit.*, 1952, p. 58, fig. 1430 i–l.

Valves linear with parallel or slightly concave sides in the middle, ends broadly wedge-shaped and very slightly produced. Longitudinal folds are formed in the middle. Keel strongly excentric and slightly constricted in the middle, keel punctæ small. Striæ coarse, somewhat wavy due to the longitudinal folds on the valve. Not common.

- Dimensions* .. Length 32.5–43 μ
 Breadth 7.5–10 μ
 Keel punctæ 12–13 in 10 μ
 Striæ 11–14 in 10 μ
- Distribution* .. India—Madras (Venkataraman, 1939), Bombay, and Partabgarh (!). Fresh-water.

Section **Lineares** (Grun.) Hustedt, etc.

42. *Nitzschia sublinearis* Hustedt

(Fig. 37)

Hustedt, F., *op. cit.*, 1930, p. 411, fig. 786; Cleve-Euler, A., *op. cit.*, 1952, p. 80, fig. 1481.

Frustules linear to linear-lanceolate in the girdle view with gradually narrowed truncate ends. Valves linear with wedge-shaped, somewhat backwardly bent capitate ends. Keel excentric, slightly constricted in the middle, keel punctæ small. Striæ fine. Not common.

- Dimensions* .. Length 40–82.5 μ
 Breadth 5–6.2 μ
 Keel punctæ 12–15 in 10 μ
 Striæ 33–37 in 10 μ

Distribution .. India—Partabgarh (!). Fresh-water.

This form agrees well with the type described and figured by Hustedt and others.

Section **Dubiæ** Grun.

43. *Nitzschia jugata* sp. nov.

(Fig. 38)

Frustula ampla ac robusta, lineari-rectangularia in aspectu zonali, apice utroque aliquantum truncato. Valvæ lineares, robustæ, binæ inter se pæne rectis ventralibus muris conjunctæ. Latera dorsalia in medio concava, gradatim in utrumque apicem tenuiora, constrictis apicibus atque aliquantum truncato-capitatis. Carina dorsalis, excentro, in medio concava, magnis crassisque carinæ punctis impariter positæ. Striæ fortes, lineatæ ac pariter positæ. Frustula 110–162.5 μ longa; 11.6–15 μ lata; carinæ punctis 6–9 in 10 μ ; striæ 12–15 in 10 μ .

Frustules large and robust, linear-rectangular in the girdle view with somewhat narrowed truncate ends. Valves linear, robust, united in pairs by more or less straight ventral walls. Dorsal side concave in the middle, gradually narrowed towards the ends which are constricted, somewhat truncate-capitate. Keel dorsal, excentric, depressed in the middle with large, thick keel punctæ placed at unequal distances. Striæ strong, lineate and uniformly placed. Rather rare.

- Dimensions* .. Length 110–162.5 μ
 Breadth 11.6–15 μ
 Keel punctæ 6–9 in 10 μ
 Striæ 12–15 in 10 μ
- Distribution* .. India—Mugud and Partabgarh (!). Fresh water.

This form somewhat resembles *Nitzschia latestriata* (Østrup) A. Cleve var. *major* Cleve (Cleve-Euler, A., *op. cit.*, 1952, p. 63, fig. 1442 a), in the outline, dorsally situated keel and the dimensions. However, this form differs from *N. latestriata* or its var. *major*, in having fewer keel punctæ, semi-wedge-shaped, constricted, truncate-capitate ends and very straight ventral side. Moreover, these frustules always were found united into pairs by the ventral side, of this fact nothing is stated in the literature. As this form appears to be distinctive, it is regarded as a new species.

Section *Lanceolata* (Grun.)

44. *Nitzschia amphibia* Grun.

(Figs. 39 a, b)

Van Heurck, *op. cit.*, 1896, p. 403, pl. 17, fig. 563; Schönfeldt, H., *op. cit.*, 1913, p. 158, fig. 349; Hustedt, F., *op. cit.*, 1930, p. 414, fig. 793; Venkataraman, G., *op. cit.*, 1939, p. 353, fig. 149; Cleve-Euler, A., *op. cit.*, 1952, p. 86, figs. 1496 a–e (*N. amphibia* v. *genuina*).

Frustules small, rectangular in the girdle view, Valves linear- to linear-lanceolate, with slightly constricted, shortly wedge-shaped, acute rounded ends. Keel excentric with large, squarish keel punctæ. Striæ strong with coarse punctæ. Common.

- Dimensions* ... Length 25–38.5 μ
 Breadth 4–5.6 μ
 Keel punctæ 7–9 in 10 μ
 Striæ 14–18 in 10 μ
 Punctæ 18–22 in 10 μ

Distribution .. India—Calcutta (Skvortzow, 1935), Madras (Venkataraman, 1939), Bombay, Kolhapur and Partabgarh (!). Fresh-water.

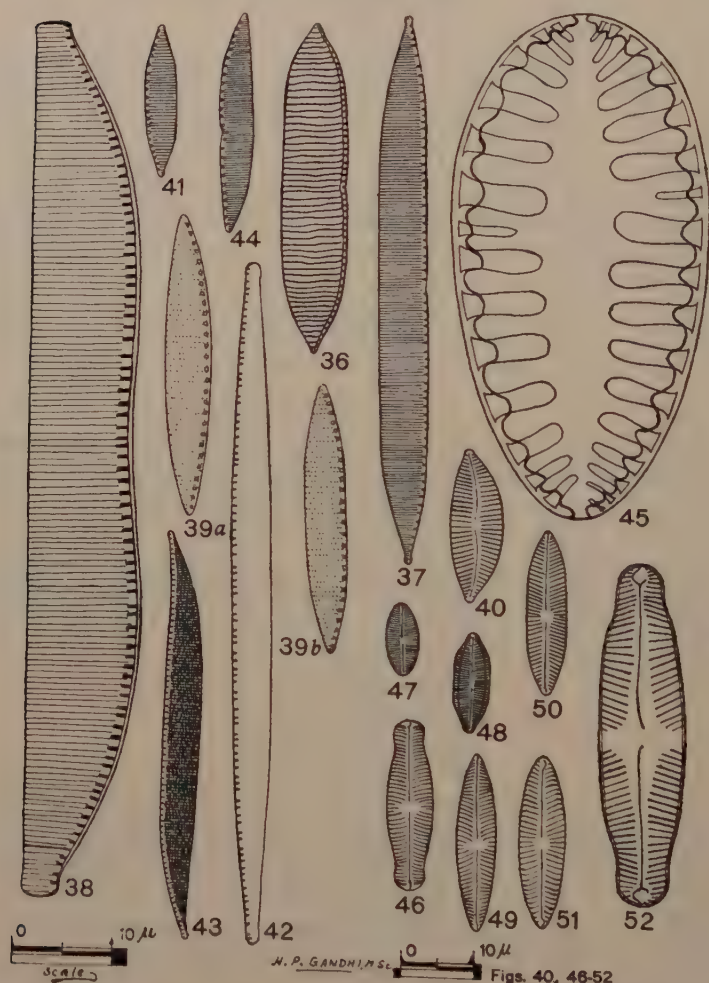
45. *Nitzschia frustulum* (Kütz.) Grun.

(Fig. 41)

Van Heurck, *op. cit.*, 1896, p. 403, pl. 17, fig. 564; Schönfeldt, H., *op. cit.*, 1913, p. 159, fig. 354; Hustedt, F., *op. cit.*, 1930, p. 414, fig. 795; Cleve-Euler, A., *op. cit.*, 1952, p. 87, fig. 1497 a, b (*Nitzschia frustulum* v. *genuina*).

Valves linear to somewhat linear-lanceolate with abruptly narrowed, wedge-shaped acute ends. Keel excentric, keel punctæ large. Striæ strong and distinct. Common.

Dimensions .. Length 21–28 μ
 Breadth 4–5 μ
 Keel punctæ 9–12 in 10 μ
 Striæ 20–22 in 10 μ



FIGS. 36–52.—Fig. 36. *Nitzschia tryblionella* Hantz. var. *levidensis* (W. Smith) Grun. Fig. 37. *Nitzschia sublinearis* Hustedt. Fig. 38. *Nitzschia jugata* sp. nov. Fig. 39 a & b. *Nitzschia amphibia* Grun. Fig. 40. *Cymbella rupicola* Grun. Fig. 41. *Nitzschia frustulum* (Kütz.) Grun. Fig. 42. *Nitzschia gandersheimensis* Krasske. Fig. 43. *Nitzschia sigma* (Kütz.) W. Smith. Fig. 44. *Nitzschia filiformis* (W. Smith) Hustedt. Fig. 45. *Surirella robusta* Ehr. forma minor f. nov. Fig. 46. *Navicula pupula* Kütz. var. *capitata* Hustedt. Fig. 47. *Navicula fluens* Hustedt. Fig. 48. *Navicula vitrea* (Østrup) Hust. Fig. 49. *Navicula cari* Ehr. Fig. 50. *Navicula vanhaeffeniformis* sp. nov. Fig. 51. *Navicula gonzalvesiana* sp. nov. Fig. 52. *Pinnularia microstauron* (Ehr.) Cleve.

Distribution .. India—Bombay, Kolhapur, and Partabgarh (!).
Fresh-water.

This form appears much like *N. amphibia* Grun., but the keel punctæ and the striæ are rather closely set and the latter are not clearly punctate.

46. *Nitzschia gandersheimensis* Krasske

(Fig. 42)

Hustedt, F., *op. cit.*, 1930, p. 417, fig. 804.

Frustules rectangular in the girdle view, slightly bent, with pale-yellow chromatophore. Valves linear to linear-lanceolate with slightly constricted, broadly rounded or somewhat capitate ends. Keel excentric with irregularly set keel punctæ. Striæ very fine and scarcely seen. Not common.

Dimensions .. Length 35–89 μ
Breadth 5.6–6 μ
Keel punctæ 8–11 in 10 μ
Striæ over 30 in 10 μ

Distribution .. India—Partabgarh (!). Fresh-water.

This form agrees well with the type described and figured by Hustedt, except that it is a little larger and broader form.

Section Sigmoidæ (Grun.) Hustedt, etc.

47. *Nitzschia sigma* (Kütz.) W. Smith

(Fig. 43)

Van Heurck, *op. cit.*, 1896, p. 396, pl. 16, fig. 531; Schönfeldt, H., *op. cit.*, 1913, p. 156, fig. 344; Hustedt, F., *op. cit.*, 1930, p. 420, fig. 813; Cleve-Euler, A., *op. cit.*, 1952, p. 74, figs. 1470 *a, b* (*N. sigma* v. *genuina*).

Frustules sigmoid, almost linear with narrow ends in the girdle view. Valves sigmoid, linear in the middle with gradually tapering, slightly constricted, produced, acute rounded ends. Keel strongly excentric, keel punctæ small. Striæ fine and punctate, punctæ of the striæ are arranged in more or less longitudinal wavy lines. Rather rare.

Dimensions .. Length 54–80 μ
Breadth 4.6–6 μ
Keel punctæ 10–12 in 10 μ
Striæ 22–30 in 10 μ

Distribution .. India—Partabgarh (!). Fresh-water.

This form agrees well with the type described and figured by Hustedt in all respects. It is mainly a brackish-water or marine form, but Cleve-Euler reports its occurrence in the fresh-water and mentions it as a rather rare form.

Section *Obtusæ* (Grun.) Hustedt, etc.48. *Nitzschia filiformis* (W. Smith) Hustedt

(Fig. 44)

Schönfeldt, H., *op. cit.*, 1913, p. 161, fig. 358; Hustedt, F., *op. cit.*, 1930, p. 422, fig. 818; Cleve-Euler, A., *op. cit.*, 1952, p. 78, figs. 1478 a, b (*N. filiformis* v. *genuina*).

Frustules small, slightly sigmoid, linear-lanceolate in the girdle view. Valves linear or slightly sigmoid with obliquely narrowed and obtuse rounded ends. Keel slightly excentric, constricted in the middle with large keel punctæ. Striæ fine but distinct. Rare.

Dimensions .. Length 25–28 μ
 Breadth 4.4–5 μ
 Keel punctæ 9–12 in 10 μ
 Striæ 33–35 in 10 μ

Distribution .. India—Partabgarh (!). Fresh-water.

This form agrees well with the type described and figured by Hustedt and others.

3. Family *SURIPELLACEÆ*(a) Sub-family *SURIELLOIDEÆ*Genus *Surirella* Turpin 182849. *Surirella robusta* Ehr. forma *minor* f. nov.

(Fig. 45)

Frustula parvæ, cuneata in aspectu zonali. Valvæ heteropolares, ovatæ, apice late-rotundato. Linea media nulla. Area media linearilanceolata. Costæ crassissimæ, ad medium versus latiores, imparibus positæ intervallis. Striæ indistincte punctatæ inter costus ut in typo. Frustula 56–66 μ longa; 31–35 μ lata; costæ 10–15 in 100 μ .

Frustules small, wedge-shaped in the girdle view. Valves heteropolar, ovate with broad rounded ends. Middle line absent. Middle field linear-lanceolate. Costæ very thick, widening towards the middle, set at unequal distances. Punctate striæ indistinctly present between the costæ as in the type. Rare.

Dimensions .. Length 56–66 μ
 Breadth 31–35 μ
 Costæ 10–15 in 100 μ

Distribution .. India—Partabgarh (!). Fresh-water.

This form resembles *S. robusta* Ehr. (Hustedt, *op. cit.*, 1930, p. 437, fig. 850), in the outline, robust walls, etc. However, it is a much smaller form and the middle line in the central field is absent. It is therefore regarded as a new form.

50. *Surirella tenera* Greg. var. *splendidula* A. S. Schm.

(Fig. 53)

Cleve-Euler, A., *op. cit.*, 1952, p. 105, fig. 1525 f.

Frustules robust, wedge-shaped in the girdle view. Valves heteropolar, ovate with broad, rounded apex and much narrowed, cuneate acute base. Middle line interrupted, towards the ends it forms spines seated on narrow cushions. Central field linear-lanceolate, fairly large. Marginal folds strongly developed with distinct projections. Costæ thick and strong with linear sides, radial at the ends. Striæ marginal, fine and almost indistinct, present in between the costæ. Not common.

Dimensions .. Length 97–114 μ
 Breadth 42–61 μ
 Costæ 18–23 in 100 μ

Distribution .. India—Bombay and Partabgarh (!). Fresh-water.

This form agrees well with the type described and figured by Cleve-Euler.

51. *Surirella ovata* Kütz.

(Figs. 54–55)

Hustedt, F., *op. cit.*, 1930, p. 442, figs. 863–64; Tiffany and Britton, *op. cit.*, 1952, p. 296, pl. 79, fig. 926; Cleve-Euler, A., *op. cit.*, 1952, p. 122, figs. 1566 a–c (*S. ovata* v. *typica*).

S. ovalis Bréb. v. *ovata* Kütz.—Van Heurck, *op. cit.*, 1896, p. 373, pl. 13, fig. 587; Schönfeldt, H., *op. cit.*, 1913, p. 170.

Frustules small, wedge-shaped in the girdle view, found embedded in brownish scum encrusting the wet rocks. Valves heteropolar, broadly ovate to ovate-lanceolate with somewhat narrower base. Pseudoraphe narrow, linear. Marginal folds scarcely developed. Costæ radial, thick, rib-like, variously reaching the pseudoraphe. Striæ very distinct and coarse, 2–5 alternating with the costæ. Abundant.

Dimensions .. Length 23–65 μ
 Breadth 21–35 μ
 Costæ 40–65 in 100 μ
 Striæ 16–20 in 10 μ

Distribution .. India—Partabgarh (!). Fresh-water.

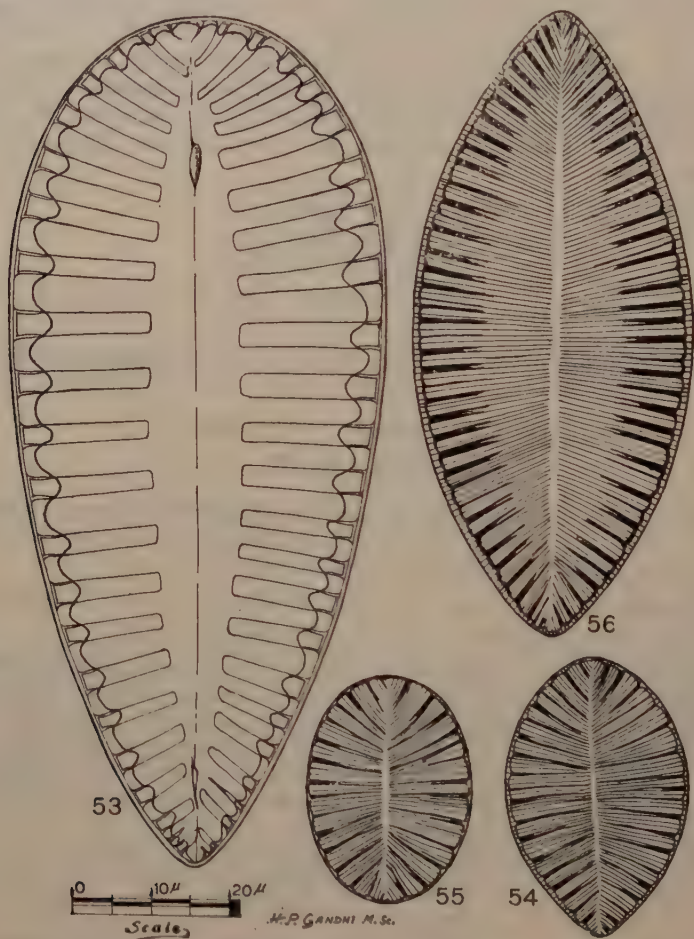
This form is a variable one, agrees very well with the type described and figured by Hustedt and others.

52. *Surirella lanceolata* sp. nov.

(Fig. 56)

Frustula magna ac robusta, aspectu medio rectangularia. Valvæ isopolaes, late-lanceolatae, apicibus acutis et rotundatis. Pseudoraphe

angustissima, linearis. Costæ costellis similes, radiales, alternæ singulis usque trinis striis validis, ad quartan partem ad latitudinem valvæ veniens. Striæ ad median valvæ partem perveniunt, et pseudoraphen angustissimum reddunt. Frustula 62-91 μ longa; 35-42 μ lata; costæ 40-60 in 100 μ ; striæ 15-19 in 10 μ .



FIGS. 53-56.—Fig. 53. *Surirella tenera* Greg. var. *splendula* A. S. Schm. Figs. 54-55. *Surirella ovata* Kütz. Fig. 56. *Surirella lanceolata* sp. nov.

Frustules large and robust, rectangular in the girdle view. Valves isopolar, broadly lanceolate with acute rounded ends. Pseudoraphe very narrow, linear. Costæ rib-like, radial, alternating with 1-3 strong striae and reaching $\frac{1}{4}$ the breadth of the valve. Striæ reach the middle part of the valve to make a very narrow pseudoraphe. Rather rare.

Dimensions .. Length 62–91 μ
 Breadth 35–42 μ
 Costæ 40–60 in 100 μ
 Striæ 15–19 in 10 μ

Distribution .. India—Partabgarh (!). Fresh-water.

This form was found embedded in the brownish scum along with *S. ovata* Kütz. It differs from *S. biseriata* Bréb. and its var. *bifrons* (Ehr.) Hust. (Hustedt, F., *op. cit.*, 1930, p. 432, figs. 831–832; p. 433, fig. 833 respectively), in not having distinct marginal folds and thick costæ. Moreover, the costæ here are rib-like and more numerous with very distinct and rather coarse striæ alternating with them. It also differs from *S. birostrata* Hust. (Hustedt, F., *op. cit.*, 1930, p. 434, fig. 841), in not having produced, acutely rounded ends, strong marginal folds, marginal rib-like costæ and marked striæ, etc. It is a distinctive form and does not resemble any other known types, hence it is regarded as a new species.

SUMMARY

For the first time the Diatomaceæ of Partabgarh Rajasthan has been investigated and almost all the forms have been fully described and illustrated in these pages.

Brief accounts of topography, climate, geology, location and the history of the place are given.

The material for the present investigation was collected from a number of pools and ditches of the drying rain-water streams which surround the town.

In all fifty-two forms have been described, representing fourteen genera; of these fifty-two forms, twenty are new records for India, six are new species and two new forms.

ACKNOWLEDGEMENT

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SOME SPECIES OF *PERICONIA* FROM INDIA

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DESPITE their very common occurrence as saprophytes on a variety of substrata, no species of *Periconia* appear to have been reported so far from this country. In recent years, I have had occasion to collect some species of this interesting genus from this country and this paper is a systematic account of the species collected by me. The recent monograph of British species of *Periconia* by Mason and Ellis (1953) has clarified many points relating to the taxonomy of this little known genus and has been of great help in the identification of some of the Indian species. *Periconia*, as reported here, is the same as that circumscribed and re-described by Mason and Ellis (1953, pp. 60-62) and all the species recorded here possess the following characteristics in common: conidia typically in chains or occasionally single, globose, one-celled, brown, nearly always rough walled, lacking any obvious hilum, produced on sporogenous cells borne directly on the stipe or its branches; conidial chains often branched, developing in acropetal succession but usually maturing from the apex backwards.

In nature the colonies may be widely effused as in *P. byssoides*, *P. obliqua* and *P. kambakkamensis*, or may be compact as in *P. hispidula* or *P. madreya*. The (macronematous) conidiophores are erect or ascending, consisting of a mononematous stipe terminated by a head of conidia as in *P. byssoides* and *P. cookei*, or flanked by lax chains of conidia as in *P. hispidula*, or characterised by the presence of a well-defined sporiferous part half way between the centre and the apex of the stipe as in *P. obliqua*. The stipe is pale to dark brown, septate, straight, bent or curved, completely unbranched as in *P. byssoides* and *P. cookei*, or producing short branches close to each other towards the apex as in *P. narsapurensis*, or producing longer branches, often widely spaced, as in *P. minutissima* and *P. paludosa*. The stipe may be apically sterile as in *P. hispidula* and *P. kambakkamensis*, or may terminate in one or more sporogenous cells bearing lax chains of conidia as in *P. tirupatiensis*.

Twelve species of *Periconia* are recorded in this paper. Of these, six are being described as new, viz., *P. narsapurensis*, *P. obliqua*, *P. kambakkamensis*, *P. madreya*, *P. tirupatiensis* and *P. clitoriae*. The other six species are: *P. byssoides*, *P. cookei*, *P. minutissima*, *P. paludosa*, *P. hispidula* and *P. laminella*, all of which have been recorded by Mason and Ellis (1953) from Britain. I have no doubt that future collections would reveal the occurrence of several other species of this genus in this country.

For ease of reference and for the sake of completeness, the following nomenclator, from Mason and Ellis (1953, p. 60), is given here:

Periconia Tode ex Schweinitz, 1822, *Synopsis Fungorum Carolinae Superioris*, p. 125.

Type species *P. lichenoides* Tode, *Fungi Mecklenburgenses selecti*, fasc. 2, p. 2, 1791.

Synonymy:

Sporocybe Fries, 1825, *Systema orbis vegetabilis*, p. 170.

Type species *Periconia byssoides* Pers. ex Schwein. (1822) = *S. byssoides* [Pers.] Fr., 1832, *Systema Mycologicum*, 3, 2, p. 343.

Sporodum Corda, 1837, *Icones fungorum*, 1, p. 18.

Type species *S. conopleoides* Corda, 1837, *ibid.*, p. 18 = *Periconia hispidula* (Pers. ex Pers.) Mason & Ellis, 1953, *Mycol. Pap.*, 56, p. 112.

Trichocephalum Costantin, 1887, *Les Mucédinées Simples*, p. 106.

Type species *T. curtum* (Berk.) Costantin, 1887, *ibid.*, p. 106 = *Cephalotrichum curtum* Berk., 1841, *Ann. & Mag. nat. Hist.*, 1, 6, p. 432 = *Periconia curta* (Berk.) Mason & Ellis, 1953, *Mycol. Pap.*, 56, p. 98.

Berkeleyna O. Kuntze, *Revisio Generum Plantarum*, 3, 2, p. 447.

Type species *B. curta* (Berk.) O. Kuntze, 1898, *ibid.*, p. 447 = *Cephalotrichum curtum* Berk. (1841) = *Periconia curta* (Berk.) Mason & Ellis (1953).

KEY TO THE INDIAN SPECIES OF *Periconia*

Conidia formed in a well-defined head at the apex of the stipe

Macronematous conidiophores without concolorous branches

Stipe with a short apical cell cut off by a septum;
sporogenous cells formed over the apex and in a
ring below the septum *byssoides* (1)

Stipe without a short apical cell; sporogenous cells
formed over its swollen apex *cookei* (2)

Macronematous conidiophores with concolorous branches

Concolorous branches at the apex

Branches very short, close together; conidia with
long spines, 15-20 μ in diam. *narsapurensis* (3)

Branches long, widely spaced, irregular; conidia
verrucose or echinulate

Conidia verrucose, 6.8-9.4 μ in diam. *minutissima* (4)

Conidia shortly echinulate, 8.5-12.0 μ in
diam. *paludosa* (5)

Conidia formed in a well-defined sporiferous part between
the centre and the apex of the stipe on one side
alone *obliqua* (6)

Conidia formed along the side of the stipe or, if at the apex,
not in a well-defined head

Apex of stipe sterile

Colonies widely effused; conidia formed in heads on short lateral branches, 4-6 μ in diam. .. *kambakkamensis* (7)

Colonies compact, small

Conidia borne about the middle of the stipe on sporogenous cells, 6-6-12-0 μ in diam. .. *hispidula* (8)

Conidia borne towards the upper half of the stipe, 8-12 μ in diam. .. *madreeya* (9)

Apex of stipe fertile

Colonies stilboid; stipe with primary and secondary branches produced from the upper half; conidia minutely verrucose, 5-9-7-7 μ in diam. .. *tirupatiensis* (10)

Colonies not stilboid, compact

Stipe unbranched, conidia 8-5-9-4 μ in diam. .. *clitoriae* (11)

Stipe often branched, conidia 10-12 μ in diam. .. *laminella* (12)

DESCRIPTIONS OF INDIAN SPECIES

1. *Periconia byssoïdes* Pers. ex Schwein. Persoon, 1801, *Synopsis Methodica Fungorum*, p. 686; Schweinitz, 1822, *Synopsis Fungorum Carolinæ Superioris*, p. 125; Saccardo, 1886, *Sylloge Fungorum*, 4, 271; Mason & Ellis, 1953, *Mycol. Pap.*, 56, p. 63.

Synonymy :

Stilbum byssoïdes [Pers.] Sprengel, 1827, *Linné's Systema Vegetabilium*, ed. 16, 4, p. 546.

Sporocybe byssoïdes [Pers.] Fries, 1832, *Systema Mycologicum*, 3, 2, p. 343; Saccardo, 1886, *Sylloge Fungorum*, 4, p. 271.

Periconia pycnospora Fres., 1850, *Beitrag zur Mykologie*, 1, p. 20; Saccardo, *Sylloge Fungorum*, 4, p. 271.

P. botrytiformis Fres., 1852, *Beitrag zur Mykologie*, 2, p. 72; Saccardo, 1886, *Sylloge Fungorum*, 4, p. 273.

The colonies on the substratum are effuse and consist of scattered conidiophores with heads of conidia, occurring singly or in small groups. The stromata are partly embedded in the substratum. The conidiophore consists of a main stipe which is unbranched, erect, straight or bent, up to 8-septate, pale to dark brown, up to 420 μ long, 16-26 μ broad at the base and 10-15 μ broad immediately below the head. Each conidiophore has an apical cell which is subhyaline, sometimes swollen, 13-14 μ long and 14-16 μ broad. The diameter of the conidial head varies from 56-70 μ . The conidia are produced on sporogenous cells formed in a ring immediately below the septum cutting off the apical cell of the stipe, and also from all over the apical cell in a similar manner. The conidia are globose, one-celled, brown, verrucose, 9-15 μ in diameter, and are produced either acropetally in short chains and maturing from apex backwards, or sometimes singly. The conidial head may get detached as a whole and the main stipe of the conidiophore may proliferate through the region of detachment of the conidial head.

The following collections of this species have been made: on dead stem, Tirumalai Hills, Andhra State, 22-8-1951, coll. C.V.S. (Herb.

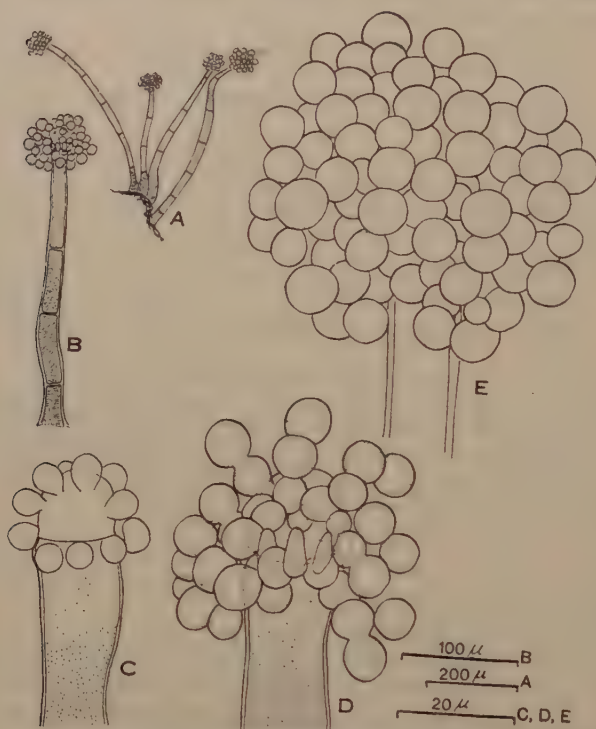


FIG. 1. *Periconia byssoides*, conidiophores and conidia. A and B from Herb. M.U.B.L. No. 382; C-E from No. 358.

M.U.B.L. No. 358); on dead stem of *Cassia* sp., Kolathuraar, Chingleput District, Madras State, 26-8-1951, coll. C.V.S. (No. 382); on dead stem, Dodabetta, Nilgiris District, Madras State, 10-10-1952, coll. C.V.S. (No. 816); on dead stem of *Artemisia* sp., Government Gardens, Ootacamund, Nilgiris District, 8-10-1952, coll. C.V.S. (No. 826); on dead twigs, Vandalur, Chingleput District, 15-8-1955, coll. C.V.S. (No. 1298); on dead stem of *Clitoria ternatea* Linn., University Botany Laboratory Garden, Madras, 18-8-1955, coll. C.V.S. (No. 1320); and on dead stem of a legume, Narsapur, Hyderabad-Deccan, 22-8-1955, coll. C.V.S. (No. 1327).

2. *Periconia cookei* Mason & Ellis, 1953, *Mycol. Pap.*, **56**, p. 72.

To the naked eye the distinction between this species and *P. byssoides* will not be obvious and in habit both are similar. This species, however, differs from *P. byssoides* in that there is no short apical cell for the stipe, but sporogenous cells arise from the swollen apex of the ultimate cell of the conidiophore. The stromata are

embedded in the substratum. The conidiophores arise from the substratum singly or in small groups. The stipe is erect, straight, bent or flexuous, dark brown below, pale brown above, 3–5-septate, $560\text{--}700\ \mu$

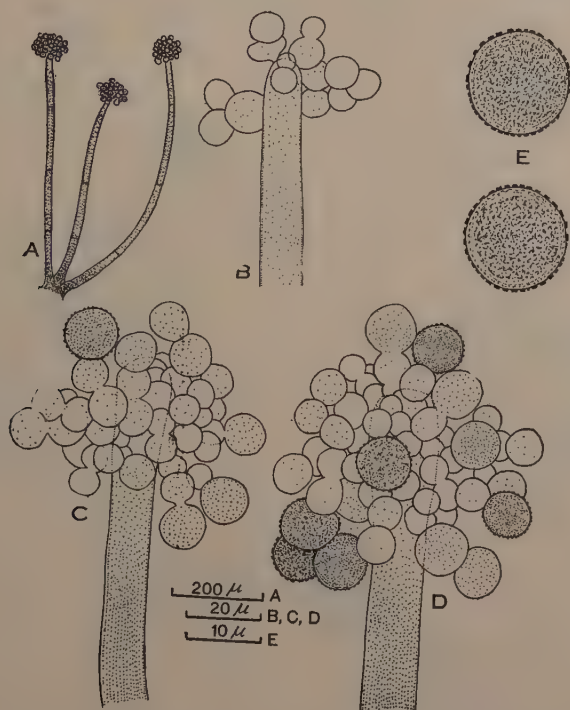


FIG. 2. *Periconia cookei*, conidiophores and conidia from Herb. M.U.B.L. No. 1330.

long, with cells $120\text{--}70\ \mu$ long, $21\text{--}25\ \mu$ broad at the base, $11.9\text{--}15.3\ \mu$ broad immediately below the head and $14\text{--}18\ \mu$ broad in the middle. The heads of conidia are spherical, pale brown when young, dark brown when mature, up to $100\ \mu$ in diameter. The conidia are globose, one-celled, brown, verrucose, $11\text{--}15\ \mu$ in diameter and are produced acropetally in short chains of two or three on sporogenous cells, maturing from apex backwards in the chains. The sporogenous cells are produced all over the somewhat swollen apex of the ultimate cell of the conidiophore and are hyaline when young but become brown later; they are spherical to obpyriform, $6.8\text{--}11.9\ \mu$ in diameter. Proliferation of the conidiophore is quite common.

Only one collection has been made: on dead stem, Narsapur, Hyderabad-Deccan, 22-8-1955, coll. C.V.S. (No. 1330).

3. *Periconia narsapurensis* Subramanian sp. nov.

During a recent visit to Narsapur, Hyderabad-Deccan, I collected a *Periconia* on dead wood which is described below.

The colonies are dull to coffee brown in colour and consist of small groups of conidiophores with heads of conidia which may be up to 400μ in diameter. The conidiophore consists of a main stipe usually

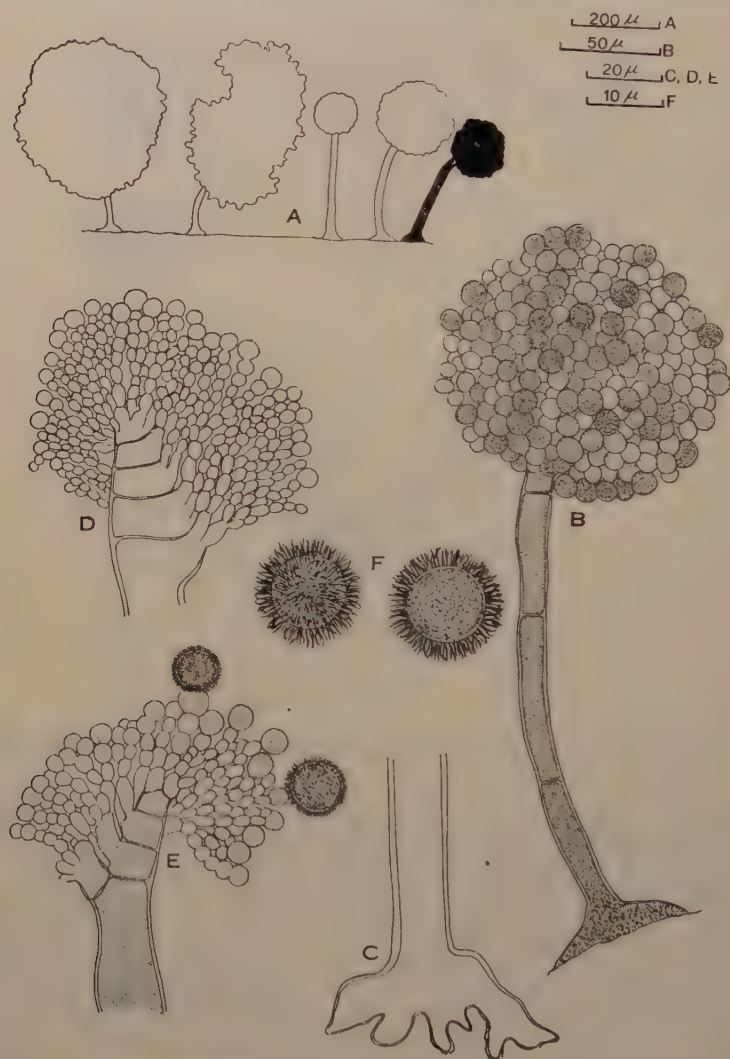


FIG. 3. *Periconia narsapurensis* from type collection, Herb. M.U.B.L. No. 1333. A, B, stipe with apical head of conidia; C, basal part of stipe; D, E, apex of stipe showing development of conidia; F, mature conidia.

bearing a globose head of numerous conidia. The stipe is erect, straight, bent or flexuous, stout, thick-walled, very deep brown, 3-4-septate, mostly $230-350\mu$ long, rarely less, $21-25\mu$ broad at the base, $18-25\mu$ broad in the middle, and $13-22\mu$ broad immediately below the

head of conidia. The apical portion of the conidiophore is closely septate and fertile, and bears usually up to five short lateral branches which are dark brown in colour, and are up to 15μ long and up to 11μ broad. These lateral branches, in some cases, appear to arise only in one plane on the fertile part of the conidiophore. The conidia are produced on sporogenous cells borne on the short lateral branches. The sporogenous cells are pale to dark brown, globose to ovoid, and $5-7\mu$ in diameter. The conidia are one-celled, globose, dark brown, beset with numerous spine-like appendages which are $5.1-6.8\mu$ long, $15-20\mu$ in diameter (inclusive of spines), and produced in simple or branched chains. Conidial development is acropetal, but those at the ends of the chains are the first to mature. In young conidial heads up to about 8 young conidia have been seen in an unbranched chain, but when mature each chain consists of numerous conidia.

This fungus appears to be sufficiently distinct from species of *Periconia* so far known and is therefore described here as a new species.

P. narsapurensis sp. nov.

Coloniæ obscuratæ vel fuliginæ, constantes acervis conidiophorum. Conidiophori singuli vel acervati, ornati capitulo sphaerico, compacto, fusco conidiorum usque 400μ diam. Stipes erectus, rectus, curvatus vel flexuosus, fusce brunneus, crassis parietibus præditus, 3-4-septatus, ut plurimum $230-350\mu$ longus, raro brevior, $21-25\mu$ latus ad basim, $18-25\mu$ latus ad medium, $13-22\mu$ latus sub ipso capitulo conidiorum. Pars apicalis stipitis arcte septata, fertilis, supportans ramos laterales breves usque ad 5. Ramuli fusce brunnei, usque ad $15 \times 11\mu$. Conidia producta e cellulis sporogenis oriundis ex ramulis lateralibus. Cellulæ sporogenæ pallide ad fusce brunneæ, globosæ vel ovoideæ, $5-7\mu$ diam. Conidia unicellulata, globosa, fusce brunnea, catenulata, spinulosa, $15-20\mu$ diam.; spinulæ conidiales plures, $5.1-6.8\mu$ longæ.

Typus lectus in ligno emortuo, in loco Narsapur, in regione Hyderabad-Deccan, die 22 mensis augusti anni 1955 a C.V.S. et positus in Herb. M.U.B.L. sub numero 1333.

4. *Periconia minutissima* Corda, 1837, *Icones fungorum*, 1, p. 19; Saccardo, 1886, *Sylloge Fungorum*, 4, p. 273; Mason, E. W. & Ellis, M. B., 1953, *Mycol. Pap.*, 56, p. 88.

Synonymy :

Periconia chlorocephala Fres., f. *minor* Saccardo, 1881, *Fungi italici*, 889 (as *Haplographium chlorocephalum* Fres. f. *minor* Sacc., Saccardo, 1886, *Sylloge Fungorum*, 4, p. 306).

P. fusca Corda f. *minutissima* (Corda) Rabenhorst, 1844, *Krypt. Fl.*, ed. 1, p. 119.

The colonies are dark brown, hairy, consisting of groups of conidiophores arising singly or sometimes in small clusters. The stipe is erect, straight, bent or flexuous, dark brown below, becoming paler above, smooth, thick-walled, up to 5-septate, with a bulbous base, cylindrical

and almost of uniform thickness above, or slightly narrowing, $320\text{--}450\ \mu$ long, up to $26\ \mu$ broad at the bulbous basal portion, $11\cdot9\text{--}15\cdot3\ \mu$ broad immediately above the bulbous base, $8\cdot5\text{--}10\cdot2\ \mu$ broad in the middle, $7\cdot6\text{--}9\cdot4\ \mu$ broad at the tip, and producing short lateral branches singly



FIG. 4. *Periconia minutissima* from Herb. M.U.B.L. No. 856. A, conidiophores with conidia; B, apex of conidiophore showing development of conidia; C, development of branched chains of conidia; D, mature conidia.

or two or three together below the apex beneath transverse septa. The branches are cylindrical, tapering towards the distal ends, at first adpressed, later spreading, brown at the base, paler above, often with 2–3 secondary branches up to $34\ \mu$ long, and $5\cdot1\text{--}6\cdot8\ \mu$ broad. The heads of conidia are ovoid to spherical, dark brown and $42\text{--}98\ \mu$ in diameter. The conidia are produced on sporogenous cells on the primary and secondary branches in simple or branched chains of usually 2–4 per chain. They are globose, pale brown in colour, smooth to minutely verrucose, $6\cdot8\text{--}9\cdot4\ \mu$ in diameter, developing acropetally, and maturing from apex backwards in the chains.

Only one collection has been made: on dead culms of *Oryza sativa* L., Poonamallee, Chingleput District, Madras State, 24-2-1953, coll. C.V.S. (No. 856). The collection agrees largely with the description given by Mason & Ellis (1953, p. 88) except for the slightly larger spores of my collection, the spore diameter as given by Mason & Ellis being 4-7 μ . I have, therefore, assigned my collection to *P. minutissima*.

5. *Periconia paludosa* Mason & Ellis, 1953, *Mycol. Pap.*, 56, p. 94.

The colonies are greyish brown and one of the two collections reported here (No. 844) was found on dead culms of grass in a marshy



FIG. 5. *Periconia paludosa* from Herb. M.U.B.L. No. 844. A, conidiophores with conidia; B, proliferation of conidiophore; C, D, development of conidia; E, mature conidia.

area. The conidiophores arise singly or in groups, bearing heads of conidia. The stipe is erect, straight, bent or flexuous, dark brown, thick-walled, up to 7-septate, 70-360 μ long, 6.6-8.3 μ broad at the base and 4.9-6.6 μ broad at the apex. The heads of conidia are loosely compacted. The stipe bears towards the tip a few lateral branches which usually arise singly, each immediately below a septum behind the apex of the stipe. These branches are pale brown in colour, short, torulose, up to 35 μ long, 4.2-5.8 μ broad, and thinner walled than the stipe. One to four such branches may be produced on each stipe towards the apex. The ultimate cells of the stipe as well as of the short lateral branches end in one or more sporogenous cells which are pale brown in colour, mostly elongate and obpyriform, occasionally globose and 5-10 \times 5-9 μ . The conidia are produced in simple or

branched chains, acropetally, on the sporogenous cells. Occasionally, sporogenous cells may be produced directly on the stipe towards its apex. The conidia are brown in colour, globose, thick-walled, verrucose to shortly echinulate, maturing from the apex backwards in the chains, and $8.5\text{--}12.0\mu$ in diameter.

Two collections of this fungus have been made: on dead culms of grass, in a marshy area opposite the University Buildings, Marina, Madras, 27-1-1953, coll. C.V.S. (No. 844); on dead straw, University Botany Laboratory Garden, Madras, 28-2-1953, coll. C.V.S. (No. 859).

6. *Periconia obliqua* Subramanian sp. nov.

This fungus was recently collected by me on dead bamboo from the Corporation Zoo Campus, Madras. It forms colonies consisting of scattered groups of brownish black conidiophores. Under a hand lens each conidiophore is seen to have a spore mass half way between its centre and its apex on one side. The stipe is erect, straight, bent or curved, brown in colour, darker towards the base, paler above, somewhat subhyaline towards the tip, broad or swollen and $11\text{--}22\mu$ broad at the base, cylindrical immediately above the swollen base, becoming progressively narrower, with pointed or rounded blunt tip, and $300\text{--}420\mu$ long. The conidia are produced on sporogenous cells which arise from a well-defined, short, sporiferous region on one side of the stipe. The sporiferous region is located half way between the centre and the apex of the stipe. The length of the stipe above the sporiferous part is $55\text{--}115\mu$. The stipe is $7.6\text{--}10.2\mu$ broad immediately below the sporiferous part and $3.0\text{--}5.0\mu$ broad at the tip. It is up to 12-septate, the septa being widely spaced (up to 70μ) below and closer ($11\text{--}26\mu$) in the fertile region. The length of the sporiferous part varies from $55\text{--}85\mu$. The conidia are produced on primary, secondary or tertiary sporogenous cells produced in one plane and on one side from the stipe cells in the sporiferous region. The sporogenous cells are pale to dark brown in colour, sub-globose, globose or obpyriform, smooth-walled and $6.8\text{--}12.0 \times 5.1\text{--}6.8\mu$. The conidia are produced acropetally in simple or branched chains, but mature from the apex backwards in the chains. The chains are short and each one has up to 4 conidia. The mature conidia are globose, pale to golden brown in colour, minutely verrucose and $8.5\text{--}10.2\mu$ in diameter. A few cases have been seen where one or two branches arise from cells of the stipe in the sporiferous region. These branches are produced on the same side as the sporogenous cells, are concolorous with the stipe except at the tip where they are subhyaline, with wavy walls towards the tip, thick-walled, up to 7-septate, up to 8.5μ thick at the base and are up to 100μ long. The branches diverge away from the stipe. The branches may be sterile, or may sometimes produce conidia on sporogenous cells arising from one or two of its basal cells. Very rarely sporogenous cells may be produced directly on the stipe above the well-defined sporiferous region and on a plane different from that in which the sporogenous cells arise in the sporiferous part.



FIG. 6. *Periconia obliqua* from type collection, Herb. M.U.B.L. No. 1364. A, conidiophore with conidia; B, conidiophore with one branch; C, part of conidiophore with two branches; D-F, portions of conidiophores showing development of conidia; G, mature conidia.

As far as I am aware, no species of *Periconia* is known to have a well-defined, short, one-sided sporiferous region half way between the centre and the apex of the stipe, as described for the fungus I have collected. My fungus is, therefore, being described as a new species.

P. obliqua sp. nov.

Coloniae constantes e catervis dispersis brunneo-nigrorum conidiophororum. Conidiophori sæpe sæpius simplices, steriles ad apicem, ornati ad medium parte sporifera brevi sed bene definita ad latus unum tantum. Stipes ut plurimum simplex, erectus, rectus, curvatus vel flexus, brunneus, fuscior infra, pallidior supra, subhyalinus ad apicem, tumescens atque $11-22\mu$ latus ad basim, cylindricus immediate supra basim tumescentum, progressive fastigatus supra, apice acuto vel hebetate vel rotundato, $300-420\mu$ longus, $7.6-10.2\mu$ latus infra partem sporiferam, $3-5\mu$ latus ad apicem, usque ad duodecies septatus, septis valde divergentibus infra (usque 70μ), approximatis in parte sporifera ($11-26\mu$). Pars sporifera stipitis $55-85\mu$ longa; pars stipitis supra partem sporiferam $55-115\mu$ longa. Conidia producta e cellulis sporogenis primariis, secundariis et tertiariis. Cellulae sporogenae pallide vel fusce brunneae, subglobosae vel globosae vel obpyriformes, leves, $6.8-12.2 \times 5.1-6.8\mu$, productae in plano unico ad unum latus stipitis e cellulis in parte sporogena. Conidia producta acropetale in catenas simplices vel ramosas, usque quaterna, maturitatem attingentia retrorsum ex apice, globosa, pallide vel auree brunnea, minute verrucosa, $8.5-10.2\mu$ diam. Stipes raro ramosus; ramuli, si adsunt, singuli vel bini, concolori stipiti, surgentes e parte sporifera, usque ad septies septati, ad 100μ longi, ad 8.5μ lati ad basim, sæpe producentes conidia ex una alterave cellula basali sporogena.

Typus lectus in culmis emortuis cannæ bambusinæ in campo "Corporation Zoo", in urbe Madras, die 9 mensis septembris 1955, a C.V.S. et positus in Herb. M.U.B.L. sub numero 1364.

7. *Periconia kambakkamensis* Subramanian sp. nov.

This fungus was collected on dead stem of bamboo from Kambakkam Hills during a visit in 1952. It forms yellowish brown to brownish effuse colonies on the substratum. The repent hyphae are subhyaline to pale brown, septate, branched and $2-5\mu$ broad. The conidia are produced both on macronematous and micronematous conidiophores. The macronematous conidiophore consists of a main stipe which is pale brown in colour, many-septate (distance between septa up to 54μ), up to 420μ long, erect, straight, bent or curved, cylindrical except towards the tip where it becomes paler and narrower with a pointed or blunt tip, minutely verrucose and $3-5\mu$ in diameter in the middle. Sometimes the stipe bears concolorous lateral branches up to 180μ long. The tips of the stipe and the concolorous branches are sterile. The conidia are produced at the apex of short lateral fertile branches on the stipe. These short lateral branches are pale in colour and are quite distinct from the concolorous apically sterile lateral branches of the stipe. Up to six such spore-bearing lateral

branches may be produced on each stipe; each branch usually consists of three cells, the lowermost being subhyaline, the longest and $10-15\mu$ long. The fertile branches may arise from any cell on the stipe, but the cells from which they arise are often shorter than the other

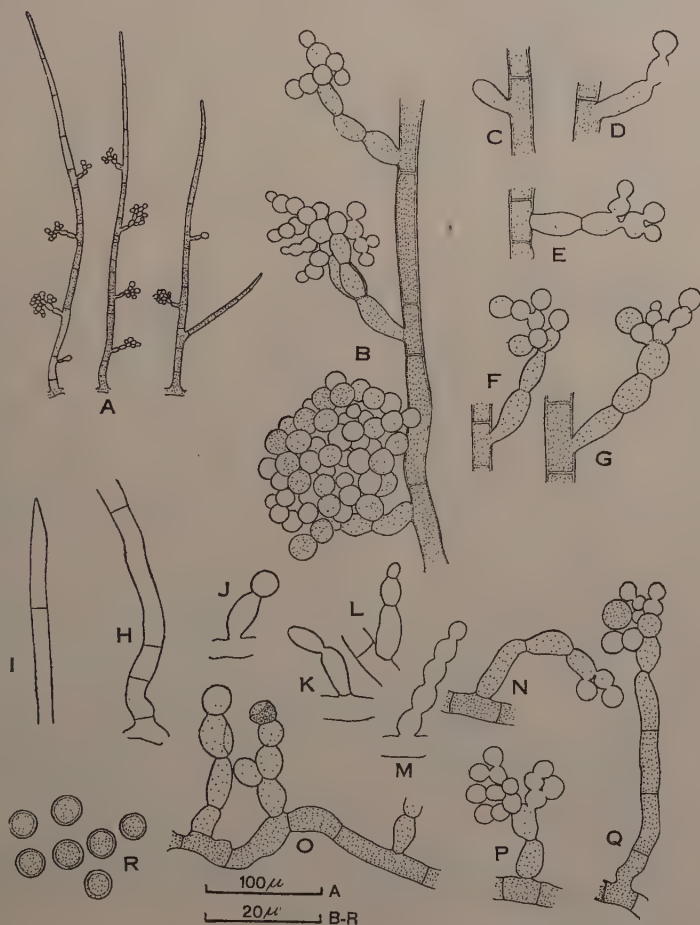


FIG. 7. *Periconia kambakkamensis* from type collection, Herb. M.U.B.L. No. 726. A, macroneumatous conidiophores; B, part of macroneumatous conidiophore with conidia; C-G, development of conidia on macroneumatous conidiophores; H, I, basal and apical parts of macroneumatous conidiophore, respectively; J-Q, microneumatous conidiophores showing the development of conidia; R, mature conidia.

cells of the stipe. The ultimate cell of each lateral branch is always a sporogenous cell; the remaining cells of the branch may also often produce conidia. The conidia often form conspicuous heads at the tips of the fertile branches. The conidia are produced in simple or branched chains on the sporogenous cells and up to 6 conidia have

been seen in an unbranched chain; they develop acropetally, but mature from the apex backwards in the chains. The micronematous conidiophores are subhyaline to pale brown in colour and may consist of short phialide-like single cells produced laterally from cells of the vegetative hyphæ and from the tips of which conidia may be abstricted singly or rarely in short chains, or else they may consist of 2-5-celled short branches arising laterally from cells of the vegetative hyphæ and producing conidia in simple or branched chains from the ultimate cell which alone is sporogenous. The conidia are one-celled, pale to golden brown in colour, globose, smooth and $4-6\mu$ in diameter.

This fungus is sufficiently distinct from species of *Periconia* so far known and is, therefore, described as a new species.

P. kâmbakkamensis sp. nov.

Coloniæ luteolo-brunnæ vel brunneolæ, effusæ. Hyphæ repentes subhyalinæ vel pallide brunneæ, septatæ, ramosæ, $2-5\mu$ latæ. Conidiophori macronematici atque micronematici adsunt. Conidiophori macronematici: stipes pallide brunneus, pluri-septatus, erectus, rectus, vel curvatus vel flexus, cylindricus, fastigatus in apicem superiorem acutum vel hebetum, minute verruculosus, usque ad 420μ longus, $3-5\mu$ latus, raro ramosus, apice sterili; ramuli laterales, usque ad 180μ longi, septati, cum stipe concolori, ad apicem steriles. Conidia producta ex cellulis sporogenis quæ insident ramulis fertilibus stipitis atque ramulis apicalibus sterilibus; ramulis fertiles pallidiores colore, sæpe sæpius constantes tribus cellulis, quarum infima longior est usque ad $10-15\mu$ longa; cellula ultima, nonnumquam cellulæ omnes ramulorum fertilium sporogenæ. Conidiophori micronematici subhyalini vel pallide brunnei, similes ramulis fertilibus stipitis, $1-5$ -cellulati, lateraliter surgentes e cellulis hypharum repentium, producentes conidia ex ultima cellula, usque ad 50μ longi, $3-5\mu$ lati. Conidia producta acropetale simpliciter vel ramosè catenulati, ad maturitatem venientia ex apice retrorsum, efformantia capitula conspicua ad apices ramulorum fertilium vel conidiophorum micronematicorum, unicellulata, globosa, crassis parietibus prædita, pallide vel auree brunnea colore, $4-6\mu$ diam.

Typus lectus in culmis emortuis canna bambusinæ in loco Kambakkam Hills, in regione Chingleput, in statu Madras, die 3 mensis februarii anni 1952, a K. Ramakrishnan & C. V. Subramanian et positus in Herb. M.U.B.L. sub numero 726.

8. *Periconia hispidula* (Pers. ex Pers.) Mason & Ellis, 1953, *Mycol. Pap.*, 56, p. 112.

Synonymy :

Conoplea hispidula Persoon, 1797, *Tentamen dispositionis methodicæ fungorum*, p. 55; 1822, *Mycologia Europæa*, Sectio 1, p. 10; Saccardo, 1886, *Sylloge Fungorum*, 4, p. 308.

Dematium hispidulum [Pers.] Fries, 1832, *Systema Mycologicum*, 3, 2, p. 365; Saccardo, 1886, *Sylloge Fungorum*, 4, p. 308.

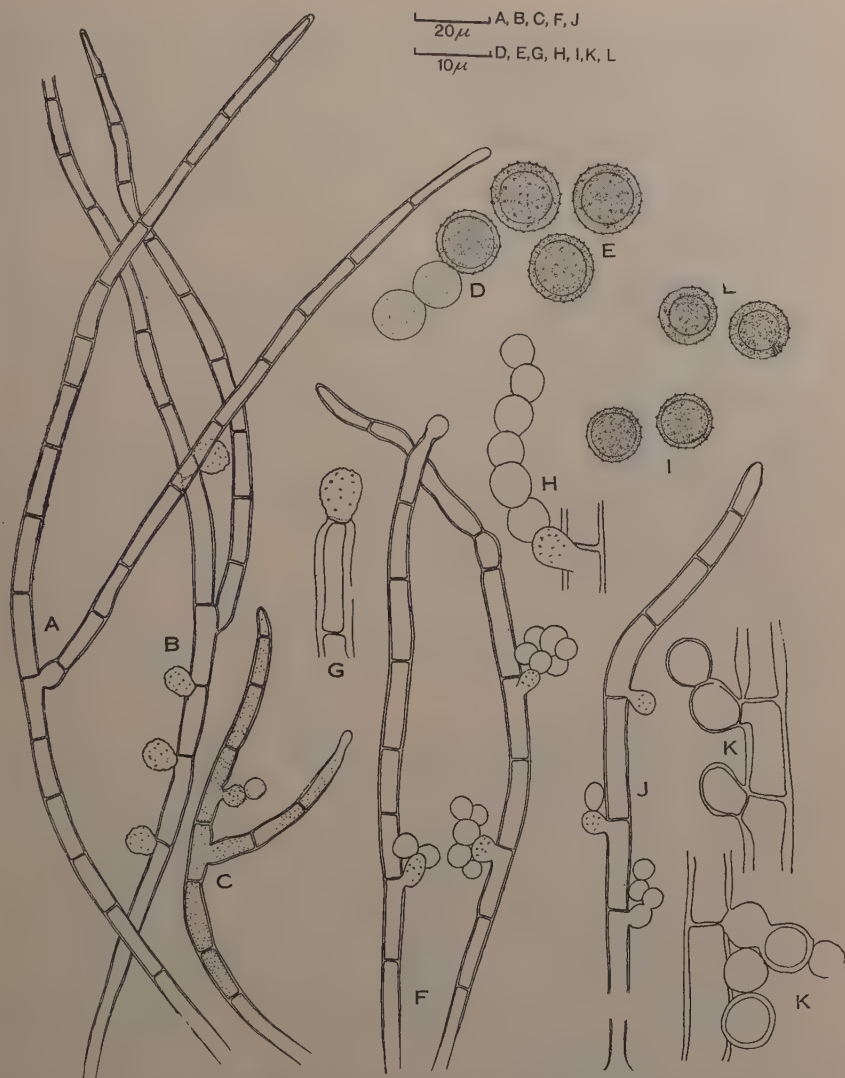


FIG. 8. *Periconia hispidula*, conidiophores, development of conidia and mature conidia. A-E, from Herb. M.U.B.L. No. 660; F-I, from No. 463; J-L, from No. 666.

Dematium graminum Libert, 1834, *Pl. Crypto. Arduennæ*, fasc. 3, No. 284; Saccardo, 1886, *Sylloge Fungorum*, 4, p. 308.

Sporodum conopleoides Corda, 1837, *Icones fungorum*, 1, p. 18; Saccardo, 1886, *Sylloge Fungorum*, 4, p. 308.

Sporodum hispidulum (Pers.) Sacc., 1881, *Michelia*, 2, 6, p. 25.

This is one of the most common fungi occurring in Southern India and I first collected it on dead leaves of *Cocos nucifera* from Ernakulam in the Travancore-Cochin State. The fungus forms globose to subglobose coffee brown or blackish brown colonies up to 1.0 mm. wide and often produced a pinkish discoloration on the substratum. The colonies are composed of compact aggregations of numerous conidiophores. The conidiophores are usually unbranched. The stipe is dark brown, conspicuously thick-walled, erect, straight, bent or flexuose, up to 16-septate, darkest in the central portion, paler towards the base, with a pointed or blunt and rounded, subhyaline tip, up to 490μ long, $4.2\text{--}6.6\mu$ broad at the base, $5.8\text{--}7.7\mu$ broad in the middle and $2.5\text{--}5.1\mu$ broad at the tip. The branches produced on the stipe were especially common in one of the collections (No. 463). The branches, when present, are concolorous with the stipe and up to 380μ long. The tips of the stipe and its branches are almost always sterile; but occasionally may be fertile. When fertile, the tip ends in a somewhat globose to obpyriform, pale to golden brown, slightly verrucose apical cell from which conidia are presumably produced; no conidia were seen attached. Sporogenous cells are produced laterally from cells of the central or sometimes even the upper part of the stipe, immediately below septa, singly or in small groups of 2-4. The sterile part of the stipe above the sporiferous region is up to a maximum of 110μ long. The sporogenous cells are pale to dark brown, globose to obpyriform, mostly verrucose, $5.8\text{--}10.2 \times 5.8\text{--}8.5\mu$. The conidia are produced acropetally in simple or branched chains, maturing from the apex backwards in the chains, dark brown, globose, thick-walled, verrucose and $6.6\text{--}12.0\mu$ in diameter.

The fungus just described comes closest to *Periconia hispidula*, as described by Mason & Ellis (1953, p. 112). There are some differences between the British collections and the Indian ones. The stipe is much shorter and somewhat thinner, the spores are smaller, and the sterile portion of the stipe above the sporiferous region is usually shorter and only rarely up to 110μ long in the Indian collections, in comparison with the British ones. No tropical collections were reported by Mason & Ellis. Nevertheless, the Indian collections are provisionally assigned to this species since they undoubtedly have a very close resemblance to *P. hispidula*.

The following collections have been made: on dead leaves of *Cocos nucifera* L., Ernakulam, T. C. State, 7-9-1951, coll. C.V.S. (No. 436); on dead stem, University Botany Laboratory Campus, Madras, 18-12-1951, coll. C.V.S. (No. 660); on dead pod of *Cæsalpinia pulcherrima* Sw., University Botany Laboratory Garden, 4-1-1952, coll. C.V.S. (No. 674); on dead stem, Kambakkam Hills, Madras State, 3-2-1952, coll. C.V.S. (No. 720); on straw, University Botany Laboratory Garden, Madras, 28-2-1953, coll. C.V.S. (No. 861); on dead leaf sheath of *Cocos nucifera* L., Thirurkuppam Research Station, Chingleput District, Madras State, 10-4-1953, coll. C.V.S. (No. 887); on dead bamboo stem, Tirumalai Hills, Chittoor District, Andhra State, 23-9-1953, coll. C.V.S. (No. 904); on dead leaves of palm, Coimbatore, Madras State, 4-10-1953, coll. C.V.S. (No. 934);

and on dead culms of *Aristida setacea* Retz., Vandalur, Chingleput District, Madras State, 15-8-1955, coll. C.V.S. (No. 1300).

9. *Periconia madreya* Subramanian sp. nov.

The fungus forms blackish brown, button-like colonies, up to 0.5 mm. wide on the substratum. Each colony consists of dense clusters of conidiophores. The conidiophores do not bear apical

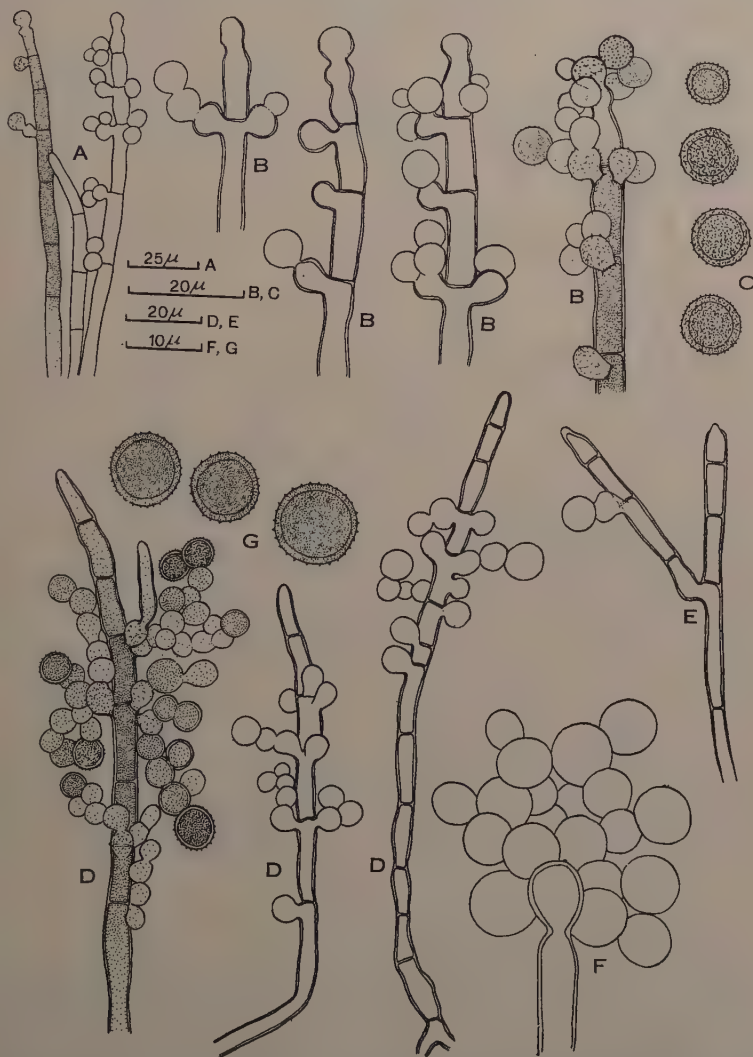


FIG. 9. *Periconia madreya*. A-C, conidiophores, development of conidia and mature conidia, from Herb. M.U.B.L. No. 263; D-G, from type collection, Herb. M.U.B.L. No. 1294.

heads of conidia. The stipe is usually unbranched and sterile at the tip, but occasionally it may be branched or may produce conidia at the tip. The stipe is erect, straight or bent, up to 12-septate, pale brown below, dark brown above, thick-walled, 125–200 μ long, 4.2–6.0 μ broad at the base, 6.0–7.7 μ broad in the middle, and 4.2–5.1 μ broad at the tip which is usually rounded and blunt. The distance between the septa on the stipe may be up to 30 μ . Usually, the sterile part of the stipe above the ultimate sporogenous cell is up to 35 μ long. The sporogenous cells are produced singly or in small groups of 2–4 from cells towards the upper half or central part of the stipe, immediately below septa. They are pale to dark brown, globose to obpyriform, verrucose, 6.8–10.2 \times 6.8–8.5 μ . The conidia are produced acropetally in simple or branched chains from the sporogenous cells, but mature from the apex backwards in the chains. They are dark brown, one-celled, globose, thick-walled, verrucose to minutely echinulate, 8–12 μ in diameter.

This fungus appears to differ from species of *Periconia* known to me and is hence described as a new species.

P. madreeya sp. nov.

Coloniæ subglobosæ vel globosæ, nigrescentes brunneæ, usque ad 0.5 mm. diam. Conidiophori producti dense fasciculati, raro fertiles ad apicem. Stipes ut plurimum haud ramosus, erectus, rectus vel curvatus, usque ad 12-septatus, pallide brunneus infra, fusce brunneus supra, crassis parietibus, 125–200 μ longus, 4.2–6.0 μ latus ad basim, 6.0–7.7 μ latus ad medium, 4.2–5.1 μ latus ad apicem, qui est rotundus vel hebes. Cellulæ sporogenæ pallide vel fusce brunneæ, globosæ vel obpyriformes, verrucosæ, 6.8–10.2 \times 6.8–8.5 μ , productæ singulæ vel binæ-quaternæ lateraliter e cellulis stipitis in superiore dimidia parte vel ad medium immediate infra septa. Pars sterilis stipitis supra ultimas cellulas sporogenas usque ad 35 μ longa. Conidia fusce brunnea, unicellulata, globosa, crassis parietibus prædita, verrucosa vel minute echinulata, 8–12 μ diam., producta acropetale in simplicibus vel ramosis catenis, maturitatem attingentia ex apice retrorsum in catenulis.

Typus lectus in culmis emortuis *Cynodontis dactyli* Pers., in horto laboratorii botanici Universitatis, in urbe Madras, die 9 augusti anni 1955, a C.V.S. et positus in Herb. M.U.B.L. sub numero 1294; species lecta etiam in culmis emortuis cuiusdam cannæ bambusaceæ in eodem loco die 6 augusti 1951 a C.V.S. et positus in Herb. M.U.B.L. sub numero 263.

10. *Periconia tirupatiensis* Subramanian sp. nov.

This fungus was collected on dead leaf rachis of *Phoenix* sp. from Tirumalai Hills, Andhra State, during a visit in 1953. It forms dark brown colonies up to half a millimeter in diameter on the substratum. Each colony consists of compact aggregations of numerous conidiophores which are fertile above. Under the microscope, each colony appears stilboid in that the lower portion consisting of the sterile parts of the conidiophores are closely compacted together parallel to each

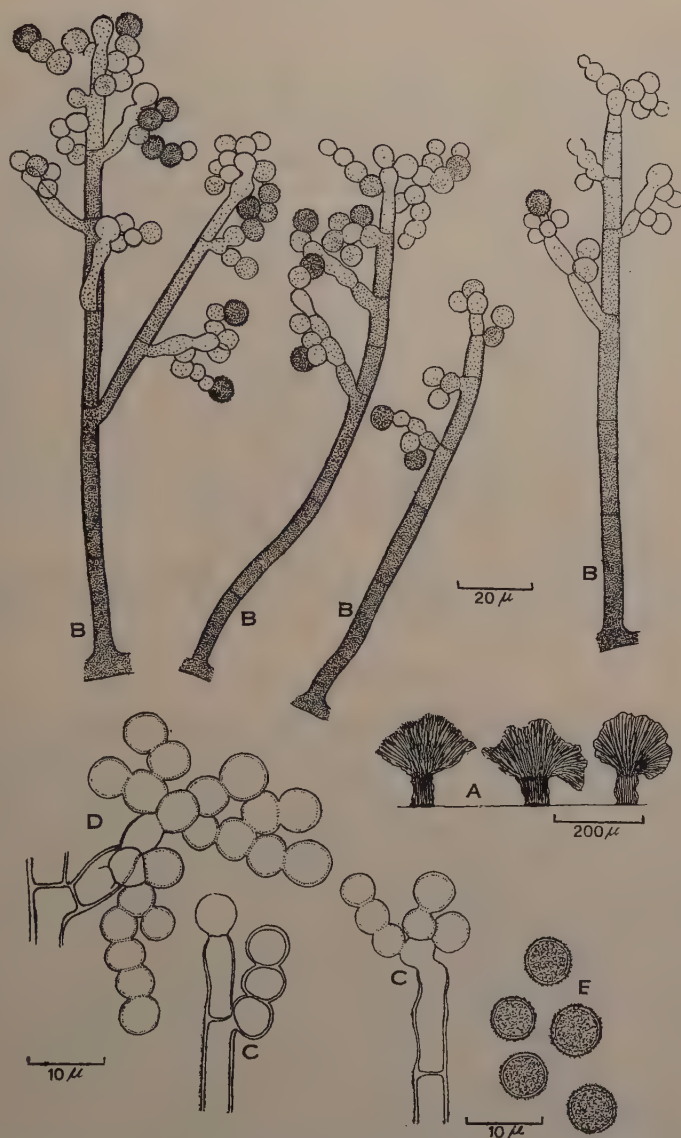


FIG. 10. *Periconia tirupatiensis* from type collection, Herb. M.U.B.L. No. 907. A, stilboid aggregations of conidiophores; B-E, conidiophores, development of conidia and mature conidia.

other, forming the short stalk of a "coremium" which is broadened out above due to the copious production of conidia in the fertile upper part of the conidiophores. The stipe is pale brown to brown in colour, thick-walled, up to 8-septate, septa being widely spaced ($28-34\ \mu$) below,

but closer to each other above, up to 210μ long, $5-7\mu$ broad at the base and in the middle portion, $4-6\mu$ broad towards the tip and terminating in a globose or obpyriform, paler coloured sporogenous cell. One to five primary branches are usually produced laterally from the cells of the stipe immediately below the apex or farther down and each branch arises from immediately below a transverse septum. The youngest and the shortest of these are produced nearer the apex, and the longer and the older ones progressively below one another. The primary branches are 1-4-septate and may be paler in colour than the stipe, $14-100\mu$ long and $4-6\mu$ broad. Secondary branches are sometimes produced and are very much shorter and fewer septate than the primary ones, up to 42μ long and $4-6\mu$ broad. The tips of the primary and secondary branches end in sporogenous cells. Sporogenous cells may also be produced directly on the fertile part of the stipe or on the primary and secondary branches as lateral outgrowths immediately below septa. The sporogenous cells are pale brown in colour, globose to obpyriform, and $5.1-7.7\mu$ in diameter. The conidia are produced in simple or branched acropetal chains, maturing from apex backwards in the chains; they are one-celled, dark brown, globose, thick-walled, minutely verrucose, and $5.9-7.7\mu$ in diameter.

I do not know of any species of *Periconia* which has all the characteristics of the fungus described above; I am, therefore, describing it as a new species.

P. tirupatiensis sp. nov.

Coloniæ fusce brunneæ, usque ad 0.5 mm. diam., stilboideæ brevibus robustisque stipitibus præditæ, supra dilatatæ. Stipes erectus, pallide brunneus vel simpliciter brunneus, usque 8-septatus, septis late separatis infra ($28-34\mu$), inter se proximioribus supra, usque ad 210μ longus, $5-7\mu$ latus ad basim atque ad medium, $4-6\mu$ latus ad apicem. Ramuli primarii et secundarii adsunt in stipite, pallide brunnei. Ramuli primarii 1-5, lateraliter producti e cellulis superioribus stipitis immediate infra septa, 1-4-septati, $14-100 \times 4-6\mu$. Ramuli secundarii usque ad 42μ longi, $4-6\mu$ lati, septati. Cellulæ sporogenæ productæ singulæ vel binæ apicaliter in stipite atque in ramulis primariis et secundariis, nonnumquam lateraliter e cellulis stipitis vel ramulorum primariorum vel secundariorum, immediate infra septa, globosa vel obpyriformia, pallide brunnea, $5.1-7.7\mu$ diam. Conidia acropetale producta simpliciter vel ramose catenulata e cellulis sporogenis, attingentia maturitatem ex apice retrorsum, unicellulata, fusce brunnea, globosa, crassis parietibus prædita, minute verruculosa, $5.9-7.7\mu$ diam.

Typus lectus in petiolis foliorum emortuorum speciei cuiusdam *Phaniceis*, in collibus Tirumalai, in regione Chittoor, in Statu Andhra, die 23 mensis septembris anni 1953, a C.V.S. et positus in Herb. M.U.B.L. sub numero 907.

11. *Periconia clitoria* Subramanian sp. nov.

This fungus was recently collected by me on dead stems of *Clitoria ternatea* from Madras. The fungus forms well-defined, coffee brown

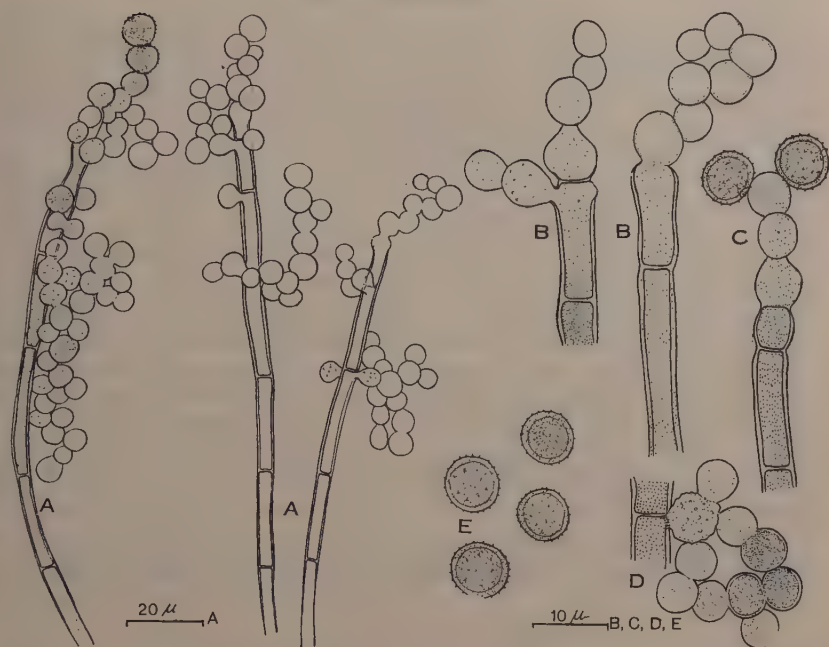


FIG. 11. *Periconia clitoriae* from type collection, Herb. M.U.B.L. No. 1321. A, conidiophores with conidia; B-D, development of conidia; E, mature conidia.

colonies on the substratum. The conidiophores arise in dense clusters. The stipe is unbranched, pale brown in colour, paler below, becoming thicker-walled and darker above, up to 5-septate, $125-180\mu$ long, $3.4-5.1\mu$ broad at the base and $5.1-6.0\mu$ broad in the middle and at the tip. The distance between the septa may be up to 45μ and is usually greater in the lower part of the stipe than the upper. The conidia are borne on sporogenous cells. The sporogenous cells are produced singly or in groups of 2-4 terminally at the apex and laterally from the upper three cells of the stipe; in the latter case, they arise immediately below septa. The sporogenous cells are globose to typically obpyriform, concolorous with the stipe, and verrucose. The sporogenous cells measure: $6.8-10.9 \times 6.8-8.5\mu$ (apical); $6.8-8.5\mu$ in diameter (lateral). The conidia are produced acropetally in simple or branched chains, maturing from the apex backwards. They are deep brown in colour, one-celled, globose, thick-walled, markedly verrucose, $8.5-9.4\mu$ in diameter.

In a classification of the genus *Periconia*, this fungus would come closest to *P. madreya* described above, but differs from it particularly in having conidiophores which are always fertile at the apex. It is, therefore, described here as a separate species.

P. clitoriae sp. nov.

Coloniæ brunneolæ, constantes e fasciculis arctis conidiophorum. Stipes haud ramosus, pallide brunneus, pallidior infra, obscuriore colore atque crassioribus parietibus præditus supra, usque ad 5-septatus, $125-180\mu$ longus, $3.4-5.1\mu$ latus ad basim, $5.1-6.0\mu$ latus ad medium atque ad apicem. Cellulæ sporogenæ globosæ vel obpyriformes, concoloræ stipiti, verrucosæ, productæ singulæ vel binæ-quaternæ apicaliter in stipite, vel lateraliter ex superioribus cellulis stipitis immediate infra septa; cellulæ apicalis sporogenæ $6.8-10.9 \times 6.8-8.5\mu$; cellulæ laterales sporogenæ $6.8-8.5\mu$ diam. Conidia acropetala simpliciter vel ramosè catenulata e cellulis sporogenis producta, maturitatem attingentia ex apice retrorsum in catenulis, alte brunnea, unicellulata, globosa, crassis parietibus prædita, distincte verrucosa, $8.5-9.4\mu$ diam.

Typus lectus in culmis emortuis *Clitoria ternateæ* Linn., in horto laboratorii botanici Universitatis, in urbe Madras, die 18 augusti 1955, a C.V.S. et positus in Herb. M.U.B.L. sub numero 1321.

12. *Periconia laminella* Mason & Ellis, 1953, *Mycol. Pap.*, 56, p. 120.

The colonies are small and brown in colour. The conidiophores differ only slightly from the vegetative hyphæ and arise laterally from

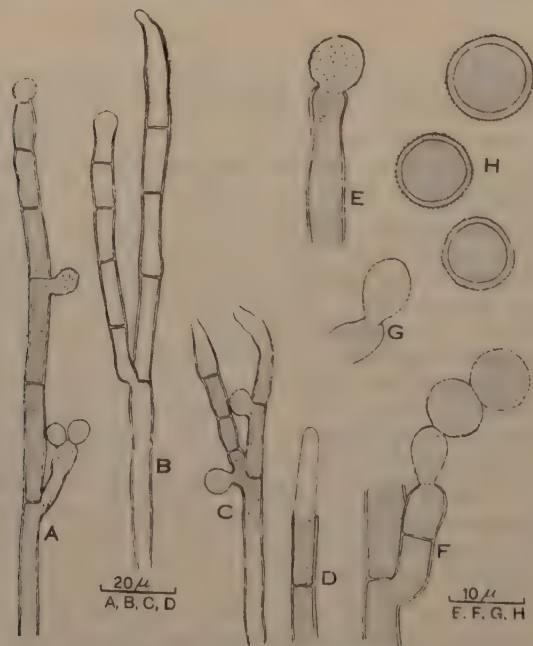


FIG. 12. *Periconia laminella* from Herb. M.U.B.L. No. 424. A-C, conidiophores with conidia; D, proliferation of the conidiophore; E-G, development of conidia; H, mature conidia.

cells of the vegetative hyphæ. The stipe is erect, straight, bent or flexuose, 2-6-septate, paler in colour and narrower at the base than above where it is somewhat darker in colour and broader, becoming dark brown towards the tip, 90-180 μ long, 3-5 μ broad at the base, 5-7 μ broad in the middle and 3-5 μ broad at the tip. The tip of the stipe is usually fertile and ends in a somewhat globose or obpyriform, golden brown, verrucose sporogenous cell. The lateral branches arising from the main stipe may be one-celled and short or up to 5-septate and long, concolorous with the main stipe, usually arising from immediately below or rarely immediately above a septum on the stipe, and 18-90 \times 5-7 μ . The tips of lateral branches are usually fertile and end in sporogenous cells on which conidia are produced in chains in the same way as at the apex of the stipe. The conidia may also be produced on globose to obpyriform, golden brown, verrucose sporogenous cells formed, usually singly, on the stipe and branches and measuring 5-13 \times 5-9 μ . The conidia are produced acropetally in chains, but mature from the apex backwards; they are subhyaline to pale brown and finely verrucose when young, globose, dark brown, thick-walled and echinulate when mature and 10-12 μ in diameter. Proliferation may take place through the broken tips of conidiophores.

Only one collection has been made: on a rotting piece of bamboo, University Botany Laboratory Garden, Madras, 30-8-1951, coll. K. Ramakrishnan (No. 424).

SUMMARY

This paper is a systematic account of Indian species of *Periconia*. Twelve species of this genus are recorded in this paper. Of these, six are described as new to science: *P. narsapurensis* on dead wood, from Narsapur, Hyderabad-Deccan; *P. obliqua* on dead bamboo, from Madras; *P. kambakkamensis* on dead stem of bamboo, from Kambakkam Hills, Madras State; *P. madreeya* on dead culms of *Cynodon dactylon* from Madras; *P. tirupatiensis* on dead leaf rachis of *Phænix* sp., from Tirumalai Hills, Andhra State; and *P. clitoria* on dead stems of *Clitoria ternatea* from Madras. The other six species are *P. byssoides*, *P. cookei*, *P. minutissima*, *P. paludosa*, *P. hispidula* and *P. laminella*, and are being recorded for the first time from this country. A key to the identification of the Indian species of *Periconia* is also given.

ACKNOWLEDGEMENTS

I am deeply indebted to the Rev. Fr. Dr. H. Santapau, Chief Botanist, Botanical Survey of India, for his ready help in translating the diagnoses of the new species into Latin. I thank the Ministry of Education, Government of India, for a grant-in-aid for travel which enabled me to collect some of the fungi reported in this paper.

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EMBRYOLOGICAL STUDIES IN THE LEGUMINOSÆ

XI. Embryological Features and Formula and Taxonomy of the Mimosaceæ*

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I. EMBRYOLOGICAL FEATURES OF THE MIMOSACEÆ

THE above series comprises ten papers (Dnyansagar, 1949, 1951 *a, b*, 1952, 1953, 1954 *a, b, c, d, e*) and the account, as presented in these papers, when carefully examined along with the previous work on this group, indicates that the Mimosaceæ possess the following features, these characters being common to all the plants investigated:—

1. The floral parts arise in acropetal succession.
2. The parietal tissue of the anther is composed of endothecium, one or two middle layers and a single layered secretory tapetum whose cells remain uninucleate throughout. The endothecium acquires characteristic fibrous thickenings at maturity.
3. Reduction divisions undergone by the microspore mother-cells are simultaneous and quadripartition takes place by furrowing.
4. Most of the members show tendency towards formation of compound pollen grains. In a few members, however, simple grains are formed.
5. Compound pollen grains are either tetrads or polyads. The individual grains are usually 3-porate. Sexine in the distal walls of individual grains is thicker than nexine. They are smooth.
6. Simple pollen grains are usually 3-colpate and sexine is thicker than nexine. They are smooth.
7. Pollen grains are bi-celled at the time of shedding excepting those of *Leucæna glauca* which are uninucleate.
8. The generative nucleus is formed towards the outer side of the grain.
9. Ovules are anatropous or campylotropous, bitegmic and crassinucellate. Integuments develop from the base. The epidermis forms a cap over the parietal tissue.
10. Archesporium is usually hypodermal and single celled. It may be multicellular in some cases but only one cell is functional. A parietal cell is usually cut off and it forms an extensive tissue. Generally, a linear and sometimes a T-shaped tetrad of megaspores is formed

* Part of a thesis approved for the Ph.D. Degree of Nagpur University.

after the reduction divisions. Usually, the chalazal and sometimes the distal megaspore functions and forms the embryo-sac.

11. The embryo-sac is elongated in shape and is usually broader at the micropylar end. It is 8-nucleate and belongs to the Normal or Polygonum type. Synergids in most cases are hooked and possess filiform apparatus. Antipodals form definite cells. Both the synergids and antipodals persist up to fertilization. Starch grains appear in the mature sac.

12. Double fertilization occurs normally. The pollen tube entry is porogamous.

13. Development of the endosperm follows the Nuclear type. The primary endosperm nucleus divides before the division of the oospore. Cell-formation takes place first in the micropylar end and then gradually extends towards the chalazal end of the sac. The chalazal part remains free nucleated for a long time and acts as a haustorium in some cases.

14. Endosperm is usually absorbed completely by the developing embryo but a trace of it remains at the chalazal end in the Eumimosæ and Adenathereæ.

15. Development of the embryo is according to the Onagrad Type, Trifolium Variation of Johansen's system or First Period, Series B of the Megarchtype VI of Souèges' embryonomique system of classification. The proembryo is of the massive type and with the exception of *Leucaena glauca*, there is no differentiation between the suspensor and the embryo proper. The author has suggested further division of the Megarchtype VI, Series B of the First Period into *c* for the reception of such plants showing the type of embryogeny that lacks a suspensor.

16. The mature embryo is symmetrical and possesses downwardly pointed short radicle, broad hypocotyledonary region and prominent cotyledons enclosing the plumule.

17. There is a single vascular strand in the ovule in the chalazal region. There takes place a post-fertilization extension of this strand in the outer integument up to the micropyle in a single hoop.

18. The mature seed is of symmetrical shape, the chalaza being at the opposite end from the hilum and raphe and antiraphe being equal. It possesses a long funicle. The testa is differentiated into the palisade or Malpighian tissue derived from the epidermis consisting of columnar cells and the mesophyll derived from the middle layers of the outer integument.

II. EMBRYOLOGICAL FORMULA FOR THE MIMOSACEÆ

It is worthwhile suggesting an embryological formula comparable to a floral formula for this family. There exists some literature on the subject which is briefly reviewed below.

In 1933, Schnarf suggested that an entire set of embryological characters of any group should be represented by the "Embryological

diagram". This point was emphasized by Maheshwari (1945) and later by Just (1946). Maheshwari made some amendments in regard to the embryological characters and suggested the term "embryological formula" for the "embryological diagram". He stated, "I believe that a stage has now arrived when we should have an embryological formula for each family as a supplement to the well-known floral formula so commonly used by systematists".

Just (1946) who advocated the use of embryological formulæ in the discussion of plant relationships, attempted to make improvement over Maheshwari's proposed annotations by means of further abbreviations. He used the embryological characters given by Schnarf (1931, 1933) and as amended by Maheshwari (1945). The following are the symbols used by him:

T—anther tapetum; g—glandular; P—pollen grain; Psi—quadripartition of microspore mother-cells is simultaneous; P/1—pollen grains uninucleate at the time of shedding; P/2—pollen grains bi-celled or binucleate at the time of shedding; Ov—ovule; ((Or))—bitegmic ovules; Or—orthotropous ovule; Ov—anatropous ovule; O γ —campylotropous ovule; c—crassinucellate; t—tenuinucellate; Nu—nucellus; Nui—integument begins near base of nucellus; My—micropyle; My/i—formed by inner integument; My/o—formed by outer integument; Ar—archesporium one-celled; Ar ∞ —many-celled archesporium; θ —parietal cell absent; !—parietal cell present; ES—embryo-sac; ESn—normal type of embryo-sac; E—endosperm; Enu—Nuclear endosperm; Em—embryo and Emo—Onagrad type of embryo development.

The author desires to suggest some changes in the symbols pertaining to the archesporium and the parietal cell. Just had represented a single-celled archesporium by the symbol "Ar" and a multicellular Archesporium by "Ar ∞ ". The author is of the opinion that "Ar" should represent only archesporium and the number of archesporial cells should be indicated by actual figures and indefinite number by the symbol " ∞ " as is done in the floral formula. For the absence of a parietal cell, he has proposed the symbol " θ " and for its presence "!". The author thinks that it would be better to reserve the symbol " θ " for the presence of a parietal cell since it indicates very well the cutting of a primary parietal cell from the archesporial cell by a horizontal wall and the symbol "0" should be used for the absence of the parietal cell. For the type of the development of the embryo, Just used Johansen's system of classification (1945, 1950). Since Souèges' system of embryogenic classification (1938, 1939, 1941, 1948 and 1951) is receiving better recognition, the author recommends its acceptance and suggests that its various types of development of the embryo should be represented by the following symbols:

First Period—I; Second Period—II; Third Period—III; Megarch-type I to VI—MI, MII, MIII, MIV, MV and MVI and Series A, B, C, etc.—SA, SB, SC, etc.

Thus when the development of the embryo is of the First Period, Megarchtype VI, Series B, it will be represented by the symbols EmI-MVI-SB.

Using Just's symbols with above modifications, the embryological formulæ have been worked out for the 17 plants of the Mimosaceæ (of these 12 studied by the author himself).

1. *Leucæna glauca*—Tg, Psi/1, ((Ov)) c, My/o, Nui, Ar1, 0, ES_n, Enu, Emo or EmI-MVI-SB.
2. *Mimosa hamata*—Tg, Psi/2, ((Ov)) c, My/2, Nui, Ar1, θ , ES_n, Enu, Emo or EmI-MVI-SB.
3. *Pithecolobium saman*—Tg, Psi/2, ((Ov)) c, My/o, Nui, Ar1, θ , ES_n, Enu, Emo or EmI-MVI-SB.
4. *Neptunia triquetra*—Tg, Psi/2, ((Ov)) c, My/o, Nui, Ar1 (usually), θ , ES_n, Enu, Emo or EmI-MVI-SB.
5. *Prosopis spicigera*—Tg, Psi/2, ((Ov)) c, My/o, Nui, Ar1 (usually), θ , ES_n, Enu, Emo or EmI-MVI-SB.
6. *Desmanthus virgatus*—Tg, Psi/2, ((Ov)) c, My/o, Nui, Ar1-3, θ , ES_n, Enu, Emo or EmI-MVI-SB.
7. *Dichrostachys cinerea*—Tg, Psi/2, ((Ov)) c, My/o, Nui, Ar1, θ , ES_n, Enu, Emo or EmI-MVI-SB.
8. *Parkia biglandulosa*—Tg, Psi/2, ((Ov)) c, My/i, Nui, Ar1, θ , ES_n, Enu, Emo or EmI-MVI-SB.
9. *Acacia auriculæformis*—Tg, Psi/2, ((Ov)) c, My/o, Nui, Ar1, θ , ES_n, Enu, Emo or EmI-MVI-SB.
10. *Calliandra hematocephala*—Tg, Psi/2, ((Ov)) c, My/o, Nui, Ar1, θ , ES_n, Enu, Emo or EmI-MVI-SB.
11. *Calliandra grandiflora*—Tg, Psi/2, ((Ov)) c, My/o, Nui, Ar1, θ , ES_n, Enu, Emo or EmI-MVI-SB.
12. *Adenanthera pavonina*—Tg, Psi/2, ((Ov)) c, My/o, Nui, Ar1 (usually), θ , ES_n, Emo or EmI-MVI-SB.
13. *Albizzia lebbek* (Maheshwari, 1931)—Tg, Psi/2, ((O \hat{v})) c, My/o, Nui, Ar1 (usually), θ , ES_n, Enu.
14. *Acacia baileyana* (Newman, 1933, 1934 a, b)—Tg, Psi/2, ((O \hat{v})) c, My 2, Nui, Ar1, θ , ES_n, Enu, Emo or EmI-MVI-SB.
15. *Neptunia oleracea* (Singh and Shivapuri, 1935) — Tg, Psi/2, ((O \hat{v})) c, My/o, Nui, Ar1, θ , ES_n.
16. *Acacia farensiana* (Narasimhachar, 1948)—Tg, Psi/2, ((Ov)) c, My/o, Nui, Ar1 (usually), θ , ES_n, Enu, Emo or EmI-MVI-SB.
17. *Mimosa pudica* (Narasimhachar, 1951) — Tg, Psi/w, ((Ov)) c, My/o, Nui, Ar ∞ , θ , ES_n, Enu, Emo or EmI-MVI-SB.

The above embryological formulæ also go to emphasize the embryological homogeneity of the Mimosaceæ. Based on them, the embryological formula for the family works out as follows :

Tg, Psi/2, ((Ov)) c, Nui, Ar1-∞, θ (usually), ES_n, Enu, Emo or EmI-MVI-SB.

III. TAXONOMY OF THE MIMOSACEÆ

A Introduction

There has recently appeared quite a considerable literature on the importance of embryology in relation to taxonomy; and, in their theoretical discussions or reviews or in the descriptions of their works, several authors, particularly Schnarf (1929, 1933, 1937), Mauritzon (1939), Souèges (1938, 1939, 1948, 1951) Maheshwari (1945, 1950), Johansen (1945, 1950) and Just (1946) have indicated that embryology can be extremely useful as a taxonomic aid and has great possibilities for the future. It can now be safely asserted that for improving existing systems of classification of the groups of Angiosperms and its orders and families, utilisation of our embryological knowledge is also necessary. It is with this view in mind that the author is prompted to discuss the bearing of embryological data obtained from his work and that of the previous workers on the present systems of classification of the Mimosaceæ.

B. Classification of the Mimosaceæ

(a) *Current Systems of Classification.*—The systems of classification of the Mimosaceæ that are in vogue are by Bentham (1875), by Baker (1879) in Hooker's *Flora of British India* and by Taubert (1894) in Engler and Prantl's *Die natürlichen Pflanzenfamilien*. Bentham (1875) has treated the Mimosaceæ as the suborder of the Leguminosæ. He divides it into five tribes, viz., Ingeæ, Acaciæ, Eumimosæ, Adenanthereæ and Piptadeniæ. Baker (1879) has divided it into two tribes, Mimoseæ and Acaciæ only on the basis of the number of stamens. Taubert (1894) treats it as the subfamily of the Leguminosæ and divides it into six tribes, viz., Ingeæ, Acaciæ, Eumimosæ, Adenanthereæ, Piptadeniæ and Parkiæ. He has followed Bentham (1875) except that he has placed *Pentaclethra* and *Parkia* in one tribe Parkiæ separated from other tribes by having an imbricate instead of valvate calyx.

The above systems of classification are almost exclusively based on external floral characters, the important ones being those of the andrœcium such as the number of stamens, their condition whether free or united and presence or absence of glands on the anthers. The only embryological character that has been used both by Bentham (1875) and Taubert (1894) is the presence or absence of the endosperm in the mature seed in distinguishing the tribes Adenanthereæ and Piptadeniæ from each other. This is, however, too gross an embryological character and one can say with every justification that for all intents and purposes, embryology has not been utilised in the classification of the Mimosaceæ.

(b) *Bearing of Embryological Data on the Systems of Classification—*

A careful examination of the embryological data as presented in the author's previous papers (Dnyansagar, 1949, 1951 *a*, *b*, 1952, 1953, 1954 *a*, *b*, *c*, *d* and *e*) and in the previous work on the Mimosaceæ (Guignard, 1881, Maheshwari, 1931, Newman, 1933, 1934 *a*, *b*, Singh and Shivapuri, 1935 and Narasimhachar, 1948 and 1951) reveals that resemblances are much more pronounced among the members of the Mimosaceæ than are the differences between them.

The characters in which the various Mimosaceæ resemble each other are already given in the beginning. There are, however, some genera such as *Leucæna*, *Neptunia*, *Prosopis* and *Desmanthus* which have the simple pollen grains while the rest which are altogether seven (as studied by the author), possess the compound grains. Then there are three genera such as *Leucæna*, *Parkia* and *Dichrostachys* which differ just in a few characters. In *Leucæna* for instance, the pollen grains are uninucleate at the time of shedding. Its archesporium is a single deep-seated cell which functions as the megaspore mother-cell. Further, while normally a tetrad of megaspore is formed, there has been reported in this genus, the formation of three megaspores in one case. And lastly, during the development of the embryo, a distinct suspensor is differentiated. In addition to these differences, abnormalities occur in this genus with regard to the tapetum in degenerating anthers. In the genus *Parkia*, there develop sterile septa in anther-lobes, a condition which appears occasionally in *Dichrostachys* but not met with in the other Mimosaceæ.

But for these differences, the Mimosaceæ can be said to be a homogeneous group embryologically and in attempting its natural system of classification—which must obviously be based on the internal characters rather than the external ones, one feels tempted to suggest that none of the existing systems of classification deserves acceptance in the light of new knowledge. Bentham (1875) and Taubert (1894) divide the Mimosaceæ into five or six tribes respectively, thereby implying that there might have been five or six lines of evolution within this group. Such a position seems to be unjustifiable in the face of the pronounced embryological similarities in the group. Baker (1879) divides the Mimosaceæ into two tribes on the basis of the number of stamens. Under each tribe, however, he places genera with simple pollen grains side by side with those possessing compound grains. This scheme of classification also, is thus, on the very face of it, unsatisfactory and should be rejected.

In the light of the embryological work on the Mimosaceæ which can now be said to be sufficiently extensive and intensive, the author desires to suggest the following:

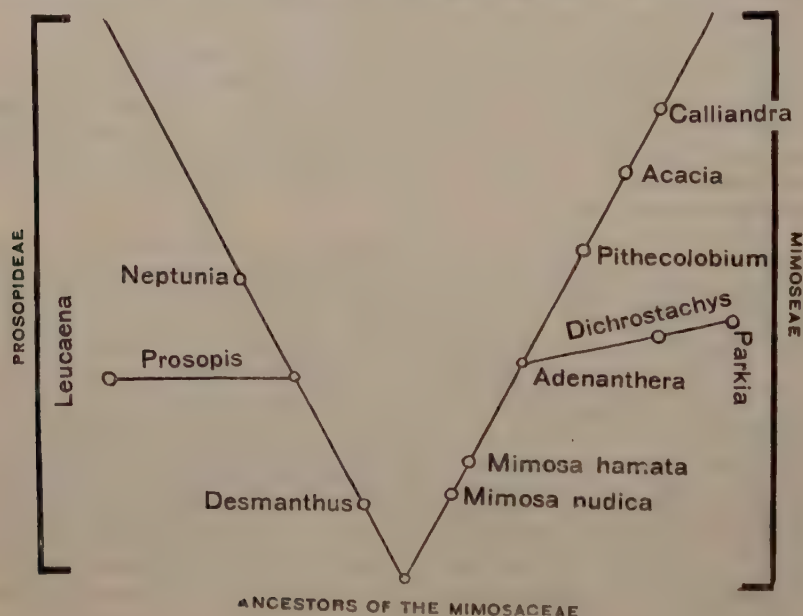
(i) On the basis of the nature of pollen grains in different genera, the Mimosaceæ should be divided into two tribes, the first one possessing simple grains and the second one with compound grains.

(ii) *Leucæna*, even though it shows deviations from the embryological features, should be placed in the first tribe because it possesses

simple grains. Its position in a phylogenetic diagram could be, however, shown as diverging along a branch from the main line of evolution of simple pollen grains.

(iii) Similarly, the genera *Parkia* and *Dichrostachys* should be placed in the second tribe possessing compound pollen grains but in view of their differences, they could be regarded as having evolved along a branch line.

(c) *Phylogenetic Representation of the Mimosaceæ and the proposed System of its Classification*—On a careful consideration of the embryological work on the Mimosaceæ, as indicated above, it can now be safely assumed that the Mimosaceæ evolved along two divergent lines, one with simple pollen grains and the other with compound pollen grains. These lines could not have developed parallel to each other because in the majority of characters, the various genera of the two lines resemble, thus suggesting a common starting point. A diagrammatic representation of the phylogeny of the group is given below:



In the two lines representing the tribes, the various genera are placed in their respective positions on the basis of such embryological characters in which they differ, these having determined their place.

In the main line with simple pollen grains, are placed three genera namely *Desmanthus*, *Prosopis* and *Neptunia* in a particular sequence so that *Desmanthus* comes first and *Neptunia* last. *Desmanthus* is assigned the most primitive position in that line on account of its possessing (a) 1-3 archesporial cells in the nucellus, (b) presence of a trace of

endosperm in the mature seed, (c) absence of chalazal free nuclear endosperm-haustorium and (d) absence of a barrier tissue in the developing seed. *Prosopis* is placed next and then comes *Neptunia*. These two genera do not show any important embryological differences and their relative position has been determined on the basis of their inflorescences and flowers. In *Prosopis*, the inflorescence is a spike and all its flowers are bisexual while in *Neptunia*, it is a globose head consisting of three types of flowers, sterile, male and bisexual. The globose head almost resembling a capitulum, is undoubtedly a higher biological feature than a spike and further, it shows a division of labour between its flowers, some being sterile, and others fertile either male or bisexual. In view of these differences, *Neptunia* is decidedly more highly evolved and should be placed above *Prosopis*. The branch line locating the position of *Leucæna* is shown as starting from the main line somewhere near *Prosopis*. It shows these two genera at almost the same level. As a matter of fact, *Leucæna* resembles both *Prosopis* and *Neptunia* in all other embryological characters except those which have been described as deviations from the normal embryological features. Since, however, *Prosopis* and *Leucæna* have arborescent habit while *Neptunia* is herbaceous, *Leucæna* must be placed as having originated somewhere at the *Prosopis* level in the main line of evolution. In spite of the divergent opinions on the primitive mode of habit, there now seems to be almost a general feeling that the arborescent habit is the older one and the herbaceous one is recently evolved. On this basis also, *Prosopis* and *Leucæna* can be placed at a lower level and *Neptunia* higher up.

The line with four genera, *Desmanthus*, *Prosopis*, *Leucæna* and *Neptunia* has been suggested to be placed as belonging to a tribe to be named as Prosopideæ. This name has been chosen after the *Prosopis* type of pollen grains in the previous genera comprised in the line.

In the other main line with compound grains, *Mimosa* is assigned the lowest position while *Calliandra* is placed at the top. Between these two genera, there occur from below upwards *Adenanthera*, *Pithecolobium* and *Acacia*. Their positions have been determined chiefly on the number of microspore mother-cells and the manner of pollinium development.

Mimosa is considered to be the most primitive genus in the line because in its important species, *Mimosa pudica* there is presence of a large number of microspore mother-cells which give rise to compound grains. Each microspore mother-cell after usual reduction divisions, forms a tetrad and this ultimately becomes a pollinium. Thus as many compound pollen grains are formed in this species as there are microspore mother-cells. In another species, *Mimosa hamata*, however, there are formed tetrads as well as polyads, each polyad being the result of a grouping of two tetrads. The number of compound grains in the species, therefore, is less than the number of its microspore mother-cells per sporangium. On account of the above differences between these species, *Mimosa pudica* is placed below and *Mimosa hamata* higher up within the range of the genus.

Adenanthera comes next in the line. Here the microspore mother-cells become separated in groups and the members of each group subsequently after usual divisions, give rise to a polyad which in course of time becomes a pollinium. There would thus be formed per sporangium, comparatively a lesser number of compound grains. This character gives to this genus the position that has been assigned to it.

In *Pithecolobium*, *Acacia* and *Calliandra* which follow after *Adenanthera*, the number of microspore mother-cells per sporangium is very much reduced and all of them remain adhered together and subsequently give rise to a single pollinium in a sporangium. *Pithecolobium* has been given the lower status as compared with *Acacia* because in it the number of microspore mother-cells is 8 while that in *Acacia* is 2-4 per sporangium. Further, while both of them show a monocarpellary pistil, sometimes in *Pithecolobium*, there are 2 carpels. *Calliandra* comes last and its highest position is determined by the following characters which are believed to be higher evolutionary characters.

(1) The very minimum number of microspore mother-cells, i.e., 2 per sporangium, (2) absence of aril, this being present in both *Pithecolobium* and *Acacia* and (3) the inner integument acting as a tapetum.

The branch line in which *Dichrostachys* and *Parkia* are located is shown as starting from the point on the main line where *Adenanthera* occurs. This is because like *Adenanthera*, these two genera possess a larger number of microspore mother-cells per sporangium and as in that genus, these cells adhere together in groups subsequently giving rise to polyads. This branch line indicates evolution in the direction of formation of sterile septa in the anther-lobes for better nutrition of a large number of sporogenous cells. *Dichrostachys* is placed lower than *Parkia* because while in the former genus, there is only occasional presence of sterile septa in the anther-lobes and there are no specialised cells along the placenta of the ovules, in the latter genus, the sterile septa in the anther-lobes are always present and along the placenta of the ovules, there is the formation of thick-walled cells. Both of these genera are shown at a little higher level than that of *Adenanthera* because they lack an aril, its absence being accepted as a higher embryological feature as indicated above. Moreover, in *Dichrostachys* where also the inflorescence is a spike as in *Adenanthera*, there is a division of labour between its flowers, some of them being sterile which serve to perform the attractive function while others are either male or bisexual and these, of course, have the reproductive function. The inflorescence in *Parkia* which is the last genus in the line also supports the position assigned to it. It is of the globose head type which is undoubtedly a higher biological feature than a spike.

The name of the tribe comprising genera in the second line of evolution is proposed as Mimoseæ after its most primitive genus *Mimosa*.

In this new scheme, the classification would be as follows:

Mimosaceæ

1. Simple pollen grains—Tribe Prosopideæ (This includes *Desmanthus*, *Prosopis*, *Leucæna*, *Neptunia*, etc.).
2. Compound pollen grains—Tribe Mimoseæ (This includes *Mimosa*, *Adenanthera*, *Dichrostachys*, *Parkia*, *Pithecolobium*, *Acacia*, *Calliandra*, etc.).

The two tribes cannot be further subdivided into subtribes, etc., because the genera under each tribe resemble each other in the majority of embryological characters. Further classification into different genera can only be on the basis of the external characters and as such shall be artificial, at least for the time being. Of course, when with more work in the field of embryology, cytology, anatomy, etc., our knowledge increases, we may be able to suggest in this part also a natural classification.

A. Simple pollen grains—Prosopideæ

(a) Anthers not gland crested

- (i) Pod ligulate, coriaceous, continuous, undershrub
with clavate stigma

Desmanthus

Tree with capitate stigma

Leucæna

- (ii) Inflorescence spike, pods fleshy and indehiscent
Prosopis

(b) Anthers at first gland crested

Herbs with flowers in globose heads

Neptunia

B. Compound pollen grains—Mimoseæ

(a) Stamens as many as petals or twice

(i) Anthers not gland crested

Calyx teeth valvate, stamens free

Mimosa

Calyx teeth imbricate, stamens monoadelphous
Parkia

(ii) Anthers gland crested

Shrubs or trees with flowers in spikes

Seeds red and arillate

Adenanthera

Seeds not arillate

Dichrostachys

(b) Stamens indefinite

Stamens free

Acacia

Stamens monoadelphous

Pod circinate

Pithecolobium

Pod falcate

Calliandra

In connection with the above proposed classification, it may be stated that Rosonoff as early as 1865 had divided the Mimosaceæ into three groups on the basis of pollen grains. His classification ran as follows:

Group I.—Genera with simple grains.

Group II.—Genera with octads.

Group III.—Genera with pollinia consisting of 8, 12, 16 and 32 cells.

In the present investigations, it has been found that quite frequently tetrads, octads and even 12 or 16-celled pollinia occur in the same species. The separation of genera from each other on the basis of the number of cells constituting a pollinium is, therefore, not justifiable. Rosonoff, however, deserves the credit of having utilised long back a taxonomic character belonging to the field of embryology and one of real importance.

ACKNOWLEDGEMENTS

The author takes this opportunity to express his deep gratitude to Professor R. L. Nirula for guidance, helpful suggestions and criticism. He is very much obliged to Shri U. Mukerjee, Principal, College of Science, Raipur for facilities, to the Ministry of Education, Government of India and to the Education Department, M.P. for research grants. He is very much thankful to Rev. H. Santapau for the word *Prosopideæ*.

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STUDIES ON THE WILT DISEASE OF COWPEA IN UTTAR PRADESH

I. Occurrence and Symptoms of the Disease and Identity of the Causal Organism

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(Received for publication on June 1, 1955)

THE occurrence of a wilt disease of cowpea (*lobia*, *Vigna sinensis* Hassk.) had not been reported from any part of India before 1954 when a preliminary account of the disease, based on field observations and some laboratory tests, was published by the author (Singh, 1954). The disease is of very common occurrence in the United States of America where it was reported more than fifty years ago (Orton, 1902). In Uttar Pradesh, India, the work has been in progress since 1953 and the results obtained so far are reported in the present paper.

IMPORTANCE OF THE CROP AND THE DISEASE

Cowpea is a common fodder and vegetable crop grown extensively during April–September in almost all the districts of Uttar Pradesh. Recently the Department of Agriculture, U.P., picked up a new variety of cowpea (*lobia* type 1), maturing in about 70 days, for testing its suitability in the different parts of the State as a possible rotation crop to replace monsoon fallows which normally precede the wheat crop. Unfortunately, under field conditions, this variety has been the worst sufferer from wilt.

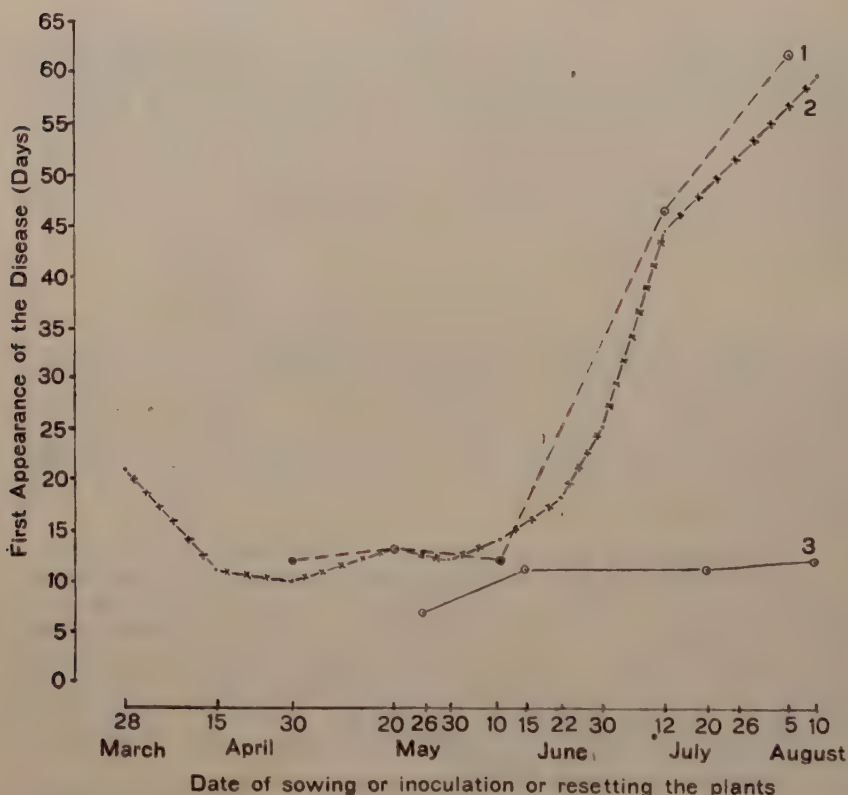
The disease was first noticed in a severe form on *lobia* type 1. It is not certain whether it was introduced through this new variety from the U.S.A. The author had noticed a similar disease on a few plants of *lobia* as early as 1948 at Buland Shahr on a fodder variety locally called 'ramas'. It is, therefore, quite possible that the fungus causing the disease had already been present in soil of this State and finding a highly susceptible host in *lobia* type 1 it became active. Field data collected during 1953–55 indicate that upto 74.6% of the plants may be killed due to the disease.

Usually the varieties grown for vegetables, yielding soft skinned pods, are found to be more susceptible than the varieties with rough pods (except *lobia* type 1) grown for fodder. The latter have exhibited a commendable degree of resistance and some appear to be immune.

SYMPTOMS

On young plants and sometimes in varieties with strong stem and short height (*viz.*, *lobia* type 1) there is sudden and outright wilting of the entire plant. In adult plants the wilting is often preceded by

yellowing of the leaves. The latter soon wither away leaving a dry naked stem. Occasionally the apex of branches dries along with the pods on the branch while the lower portion of the plant remains green or yellowish green. During continued humid weather the dried pods, and the seeds if any, bear a pinkish white fungal growth. Complete or partial blight of individual leaves sometimes precedes the death of the plant. In some varieties with weak and climbing stem there is usually gradual drying of the stem and leaves from the top downwards. In such cases the death of plants is not sudden and the process of wilting may take two to three weeks in reaching the stem-base.



TEXT-FIG. 1. Effect of date of sowing or inoculation or resetting the inoculated plants on the time of first appearance of lobia wilt in pathogenicity tests.

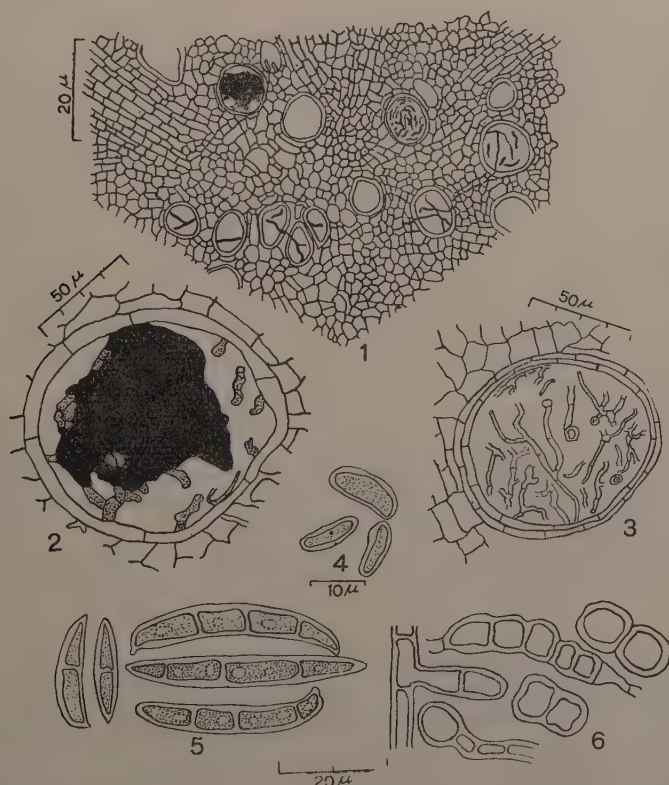
Curve 1. Time of first appearance of lobia wilt as affected by the date of sowing in inoculated pots followed by root injury.

Curve 2. Time of first appearance of lobia wilt as affected by the date of sowing in artificially inoculated soil.

Curve 3. Time of first appearance of lobia wilt as affected by the date of resetting the plants after root pruning and inoculation with spore suspension.

The roots of affected plants are usually dark in colour and devoid of laterals. Black streaks or patches may be found below the hypocotyl. In sections across the affected roots brown colouration of the xylem is common. Fungal hyphæ have been traced in the roots as well as in the stem and also in the green branches whose apical portions have dried up. In the early stages of the disease the xylem vessels nearest the pith contain the maximum amount of hyphæ. With the advance of the disease most of the vascular tissues contain a network of fungus filaments (Fig. 1). In still more advanced stages, all the xylem elements and some of the cortical parenchyma are found to be invaded by the hyphæ.

On wilted plants that remain standing in the field and on dry parts of the slowly wilting plants *Sclerotium bataticola* invariably produces numerous sclerotia. The fungus reaches the interior tissues and the sclerotia may be seen in the central cavity of the stem and some other cells (Fig. 2).



TEXT-FIGS. 2-6. 1. Presence of *F. oxysporum* f. *tracheiphilum* and *Sclerotium bataticola* in the xylem vessels of a root of badly affected plant. 2. Enlarged view of a xylem vessel showing hyphæ and sclerotium of *S. bataticola*. 3. Enlarged view of a xylem vessel showing hyphæ of *F. oxysporum* f. *tracheiphilum*. 4. Microconidia. 5. Macroconidia. 6. Chlamydospores.

ISOLATIONS AND INOCULATION EXPERIMENTS

Isolations made from roots of affected plants always yielded cultures of a *Fusarium* sp. and sometimes those of *Neocosmospora vasinfecta* Smith and *Sclerotium bataticola* Taubh. *S. bataticola* usually appears in isolations made from roots of plants in advanced stages of the disease. The latter two fungi were found to be non-pathogenic on cowpea in repeated tests. Further work was carried out with single spore cultures of the *Fusarium* sp.

Three sets of experiments were conducted in pots with a view to studying the pathogenicity of the fungus under conditions that were considered to affect the nature of its parasitism. In the first set pots were filled with autoclaved soil, mixed with one month old growth of the fungus on maize-meal-soil medium, and surface disinfected seeds of lobia type 1 were sown in each pot. In the second set when the plants, growing in the infested soil, were about three inches in height their underground portion was injured with the help of a scalpel moved into the soil around the roots. The third set of experiments consisted of plants raised in uninoculated soil. These plants, when about three inches in height, were carefully taken out, their roots washed and partly pruned, and then immersed in a thick spore-suspension of the fungus for 30 minutes. These plants were then reset in fresh pots. Appropriate check pots were maintained for each experiment.

The results obtained from these experiments have shown that the fungus isolated from wilted plants does cause the disease in artificial inoculations. The disease, however, appears earlier in pots sown during March to June than when sown during July and August (Fig. 1). From the results of the second set of experiments it has been observed that injuring the underground parts failed not only in affecting any appreciable increase in the disease-incidence but also in bringing about its earlier appearance when compared to that of the first set.

In the third experiment with root-pruning the plants remained sickly till 2-3 days after resetting. On the fourth day, however, the check plants recovered completely and resumed normal growth while the inoculated plants, after gaining turgidity of leaves, started yellowing and withering in 7-11 days and died within 14 days. It has also been seen (Fig. 1) that this technique induced the disease to appear earlier and uniformly irrespective of the season of the experiment.

CROSS-INOCULATION EXPERIMENTS

The isolate of *Fusarium* sp., obtained from roots of cowpea plants, was tested for its parasitism on a number of leguminous plants. The two methods are described earlier, *i.e.*, sowing in inoculated soil, and planting seedlings in autoclaved soil after washing, pruning, and inoculating the roots with spore-suspension were tried in these experiments also. From the results obtained it has been proved that the *Fusarium* sp. isolated from cowpea plants was pathogenic only to cowpea, but not to the other leguminous plants, namely soybean [*Glycine max* (L.) Merrill.], clusterbeans (*Cyamopsis psoraloides* DC),

TABLE I

Macroscopic Characters of the Cowpea Wilt Fusarium on Different Media at Room Temperature (24°-28° C.)

Characters	M E D I A					
	Oat agar	2% potato dextrose agar	Steamed rice	Potato plugs	Steamed	
					<i>Melilotus</i> stem	Arhar stem
Mycelial growth	..	Cottony in early stages, later scanty	Mostly submerged, sometimes cottony	Cottony	Scanty	Scanty
Colour of aerial mycelium	..	White, sometimes lilac	White to purple	White to dark pink or wine colour	White	White
Colour of the substratum	..	Normal	Dark	Wine colour to violet	..	..
Odour	..	None	None	None	..	..
Sporodochia	..	Numerous, cream to flesh coloured	Few, cream to flesh colour	None	Numerous large, cream or salmon colour	Few, small, cream to salmon colour
Pionnotes	..	Few pseudopionnotes	None	None	None	None
Sclerotia	..	None	None	None	None	None

gram (*Cicer arietinum* L.), peas (*Pisum sativum* L.), sweet pea (*Lathyrus odoratus* L.), lentil (*Lens esculenta* Moench), urd (*Phaseolus radiatus* L.), and *Sesbania aegyptiaca* L.

MORPHOLOGY, CULTURAL CHARACTERS AND IDENTITY OF THE FUNGUS

The media most commonly used for studying the morphology and cultural characters of the fungus were oat agar and two per cent. potato-dextrose agar. In addition, the pigmentation, development of sporodochia and pionnotes was also studied on steamed rice, herbaceous and woody stems, and on potato plugs. Transfers of the fungus to all the media were made on the same day from single spore lines. The cultures were kept at room temperature (24°–28° C.) under identical conditions of light. Examination of the cultures was done on the 8th, 15th and 21st day after inoculation. The microscopic and macroscopic characters are summarised in Tables I and II.

TABLE II

Characters of Conidia and Chlamydospores of Cowpea Wilt Fusarium on Different Media at Room Temperature (24°–28° C.)

MEDIA	Microconidia	Macroconidia	Chlamydospores
Oat agar ..	Common, ellipsoidal, unicellular; 5.4–14.4 microns by 1.8–3.6 microns (5.7 × 2.6) in size	Slightly curved, mostly 3-septate, rarely 2 or 4-septate: 23.4–36.0 by 3.3–4.4 microns in size; average 31.2 × 3.9 microns	Ellipsoidal to round, terminal or intercalary, unicellular, measuring 5–10 microns in diameter
Steamed potato plugs	As above	Shape as above. Size 25.2–37.8 by 2.9–4.1 microns, average 33.1 × 3.6	..
Steamed <i>Cajanus</i> stems	..	Shape as above. Size 21.6–41.4 by 3.2–4.1 microns, average 35.1 × 3.9 microns	..

The diseased specimen and the cultures of the fungus were sent to Dr. N. Prasad* of Institute of Agriculture, Anand, and he has suggested the fungus to be a form of *Fusarium oxysporum* Schl., as amended by Snyder and Hansen (1940) to agree with the description of section *Elegans* given by Wollenweber (1913). The characters of the fungus given herein and the fact that it parasitises only cowpeas makes it identical with *Fusarium oxysporum* f. *tracheiphilum* (E. F. Sm.) Snyder and Hansen (*Fusarium tracheiphilum* E. F. Sm.) as described by Orton (1902), Cromwell (1917) and Wollenweber and Reinking (1935).

* Our sincere thanks are due to Dr. N. Prasad for his kind help in the identification of the fungus.

SUMMARY

The occurrence of a wilt disease of lobia (cowpea, *Vigna sinensis* Hassk.), caused by *Fusarium oxysporum* f. *tracheiphilum* (E. F. Sm.) Snyder and Hansen, has been reported from Uttar Pradesh, India.

The disease is of wide occurrence in the State and is causing much damage to a newly introduced variety (lobia T. 1). There is a well marked periodicity in the occurrence of the disease. Crops sown during summer (March-June) suffer more than those sown during monsoons.

In pathogenicity tests the appearance of the disease is hastened when the roots are injured and dipped in a spore suspension of the fungus. The fungus is selectively pathogenic on cowpea alone but not on several other legumes tested.

ACKNOWLEDGEMENTS

Our sincere thanks are due to Dr. B. L. Sethi, Ex-Principal and now Additional Director of Agriculture, U.P., for providing encouragement and facilities for these studies. We are also grateful to Dr. B. Singh, Professor of Botany, for going through the manuscript and to Dr. T. R. Mehta, Economic Botanist (Oilseeds and Pulses) to Govt., U.P. for valuable suggestions during the course of these investigations.

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ON THE MORPHOLOGY OF TWO ABNORMAL GYNÆCIA OF *PEGANUM HARMALA* L.

BY R. D. SHUKLA

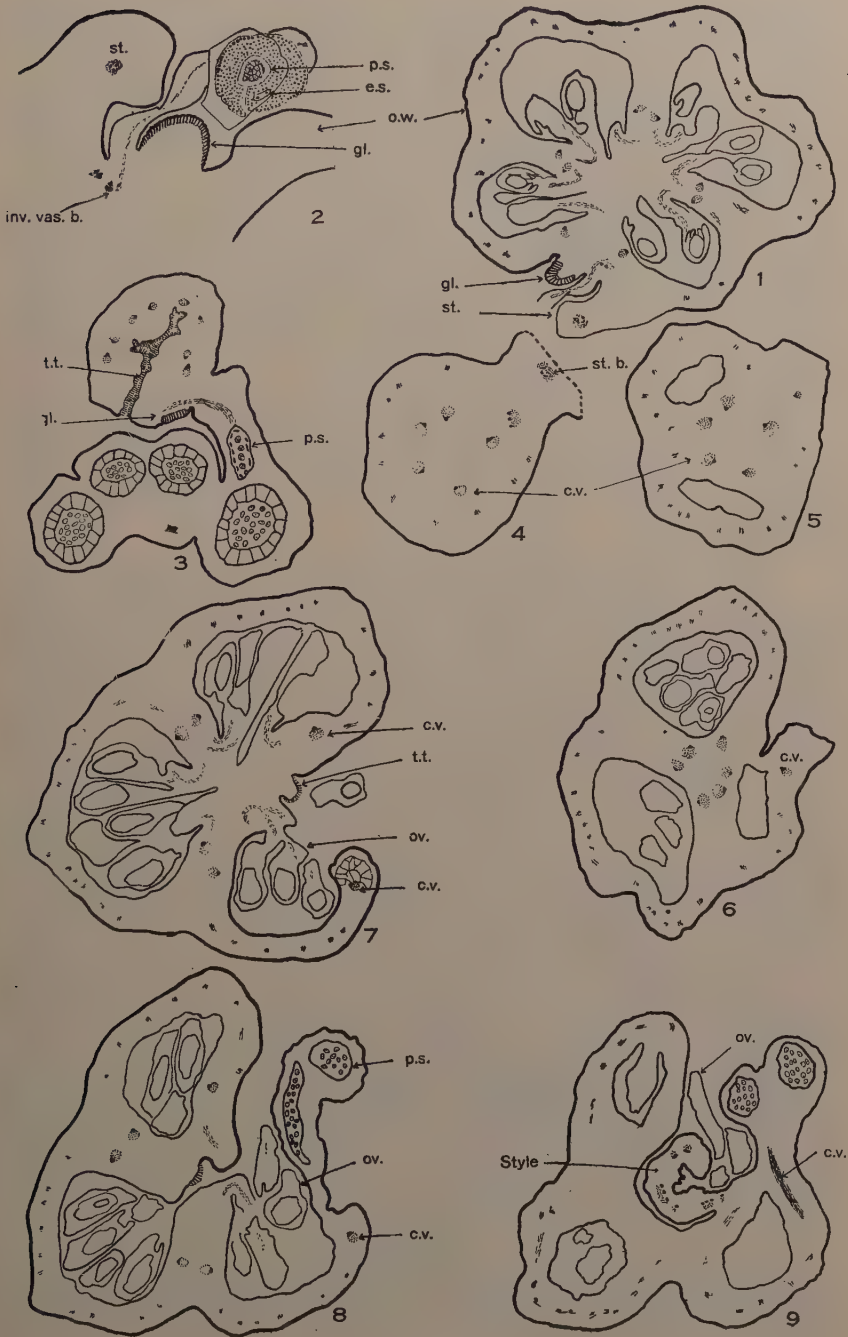
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Peganum, a genus of the family Zygophyllaceæ is a small sized perennial herb. Its white pentamerous, solitary, terminal flowers have about fifteen stamens arranged in two whorls, of which the outer consists of five and the inner of ten stamens. The ovary is deeply lobed and 2-4 celled in cross-section. Studies on the floral morphology of *P. harmala* collected from Nagaur (Rajasthan), revealed two abnormal gynæcia. The number of such cases reported in the literature is few, hence the observations are briefly recorded here.

In one case a stamen was found attached to the ovary wall, to which is also attached an "extra-locular abnormal ovule" on a filamentous appendage. In another, there is an open loculus bearing a stamen on the opened margin of the carpel which continues twisted with the style up to the stigma.

These abnormalities were studied in serial transverse sections. In the first case it was observed that the ovary is tetralocular and tetraplacental, each placenta having a pair of inverted ventral strands. On one side of the ovary wall there arise two prominent outgrowths, one is non-vascular and glandular and the other a flap-shaped structure (Fig. 1). The anatomy and the histology of the latter is that of a typical staminal filament in this species. In between the staminal outgrowth and the glandular protuberance a filamentous prolongation arises which soon becomes twisted and bears a bilobed structure (Fig. 2). One of the lobes shows an anther loculus containing degenerated tapetum and microspore mother cells, while the other encloses a binucleate embryo sac with two integument like coverings on one side (Fig. 2). There is an inverted vascular bundle present at the base of the filament, it gives out a branch that supplies the filamentous appendage right up to its apex (Figs. 1, 2), and itself enters the tissue through which the stamen is confluent with the ovary wall (Fig. 3). The glandular protuberance and the stamen continue with the style and the latter ends into a broad and expanded anther which bears four pollen sacs containing uni-celled pollen grains and degenerated tapetum. Very soon a fifth pollen sac appears near the stylar region, in the path of the inverted vascular supply (Fig. 3), containing pollen tetrads with degenerated tapetum. Apparently the carpellary tissue has got transformed in the formation of this extra anther-loculus. Similar development of the pollen sacs in the ovary wall has also been reported by Chamberlain (1897) and Hagerup (1938) in *Salix*, Rao (1940) in *Dianthus*, Farooq (1952) in *Citrus* and Johri and Tiagi (1952) in *Cuscuta reflexa*. Some



FIGS. 1-9. Figs. 1-3. Transverse sections of the ovary showing the extra-locular abnormal ovule, non-vascular glandular outgrowth and a flap-shaped staminal outgrowth bearing anther loculi. Fig. 1. Showing a prominent staminal appendage, a glandular outgrowth and a filamentous outgrowth in between. Fig. 2. The filamentous appendage in between the glandular ridge and the staminal outgrowth, bearing an "extra-locular abnormal ovule," showing a binucleate embryo-sac and a pollen-sac containing microspore mother cells. Fig. 3. The fifth pollen sac has developed in the path of vascular supply. Note the carpellary ventral bundles lying in pairs of each carpel. Figs. 4-9. Transverse sections of the ovary showing an open loculus bearing a stamen on the opened margin of the carpel. Fig. 4. Showing the stamen with staminal bundle confluent with the ovary wall. One of the carpellary bundles moves outwards. Fig. 5. The prominent protuberance left after the fading away of the vascular bundle of the confluent stamen. Fig. 6. Three loculi one of them smaller, a ventral divided and the other has migrated towards the periphery in the protuberance. Fig. 7. The carpellary margin of the open carpel has developed pollen sacs. Fig. 8. The protuberance has disjoined from the ovary wall, making the loculus open, it has half placenta bearing ovules. Note that the histology of the protuberance is that of a typical staminal filament in this species. Fig. 9, the same; the open loculus has again closed.

c.v., carpellary ventral; e.s., embryo-sac; gl., glandular tissue; inv. vas. b., inverted vascular bundle; ov., ovule; p.s., pollen sac; st., stamen; st.b., staminal bundle.

interesting cases of the development of asymmetric anthers with supernumerary loculi have also been reported by Capoor (1937) in *Holoptelea integrifolia*.

In the second case, one of the stamens has become confluent with the ovary wall (Fig. 4) but its vascular trace soon fades away leaving a prominent protuberance on the ovary wall on one side (Fig. 5). In this protuberance one of the ventral bundles of a smaller loculus migrates (Fig. 6) and ultimately occupies the position formerly occupied by the staminal bundle. The remaining single ventral bundle of this smaller loculus which is small in size divides rather prematurely giving rise to a placental strand (ovular trace) and thus apparently compensates for the second ventral that has moved to the periphery. The histology of the protuberance resembles that of a typical staminal filament (Fig. 7). It very soon disjoins from the ovary wall rendering the loculus open and exposing the ovules to the exterior (Figs. 7, 8). The occurrence of the open carpels has also been reported in *Sassafras officinale* (Baillon, 1868-70), *Begonia semiperlorens* (Dummer, 1912), *Lychnis* (Snow, 1923), *Beta vulgaris* (Archimovitch, 1931), and *Ulmaceae* (Finn, 1935; Leliveld, 1935). The ovules borne by the "open carpel" in *Peganum harmala* are perfectly healthy and structurally similar to those present inside the normal loculi. The open loculus again becomes closed (Fig. 9) by the ingrowth of the carpel margin which meets the outer that has developed anther loculi (Figs. 8, 9) and continues with the partially opened style, curiously twisted up to the stigma. The cavity of the style is glandular and near its basal region some of the ovules of the "open carpel" protrude (Fig. 9). The presence of the open style with ovules has been described by Capoor (1937) in *Holoptelea integrifolia*.

DISCUSSION

A study of the "open carpel" gynæcium of *Peganum harmala* revealed that a loculus is opened, because of the disunion of the carpellary margin, exposing the ovules to the exterior. The ovules under

similar conditions have been described as "Gymnospermous" by Dummer (1912) and "Naked" by Finn (1935). A search in the literature of the abnormally developed ovules indicates that the term "naked ovule" has been loosely applied to the ovules under different conditions: Baranov (1927) described the berry in *Vitis vinifera* and used the term for the protruding naked seed; Farooq (1952) correctly used the term naked and gymnospermous as synonymous and applied it for the ovules on the outer surface of the ovary wall of *Citrus*. Capoor (1937) employed it for the few cases in *Holoptelea integrifolia* where the ovules occur in the open stylar canal. Fotidar (1939) described an abnormal case in *Galphimia gracilis* where the ovule has shifted from its normal position close to the base of the style. Bambacioni-Mezzetti (1937) and Fotidar (1939) objected to the use of the term gymnospermous, for open carpel bearing ovules, on the ground that such ovules do not develop into seeds. This argument seems inappropriate. In my opinion, the question whether such ovules develop into seeds or not does not arise. As such cases "consist largely of individual specimens whose peculiarities may never recur"; it is therefore difficult to find all required stages. The possibility of their developing further cannot be completely ruled out especially when they show normal reproductive structures. Moreover Baranov (1927) has noted perfect seeds on the fruit wall of *Vitis vinifera* and Capoor (1937) has reported the fertilized embryo sac with several endosperm nuclei in a naked ovule of *Holoptelea integrifolia*. The important criteria in designating such ovules should be their morphological topography rather than developmental morphology. The open carpel ovules resemble the ovules of gymnosperms in the sense that they are exposed. The term "naked-ovule" and the "gymnospermous-ovule" are to be taken as synonymous. Schleiden (1837)* used the term naked for describing the ovules of most of the Rubiaceæ and Oleaceæ which were erroneously believed by him to be devoid of an integument (Lloyd, 1902; Fagerlind, 1937).* It is here suggested that the ovules without integuments, be called "extegmic".

The development of a bilobed structure on an elongated outgrowth of the ovary wall in the first gynæcium, bearing a pollen cavity in the lower lobe and a binucleate embryo sac in the upper, may be interpreted as carpellary, as it receives an inverted vascular supply (Fig. 1) probably originated from one of the ventrals of the carpels.

Though the ovule in this case differs structurally from those present inside the loculi in the sense that it lacks the typical integuments, yet it can be designated as "extra-locular abnormal ovule", the abnormality being that it occurs outside the loculus, bears a pollen cavity and lacks proper integuments.

The presence of the stamen on the ovary wall in the first case and the development of the pollen sac on the carpellary margin in the second may be explained as staminal and carpellary respectively on the basis of their vasculature and topography.

* Quoted from Maheshwari (1950).

Various causes have been assigned to the formation of abnormalities by different authors. Baranov (1927) described the protruding seeds in the berry of *V. vinifera* due to vegetative mutation. Abraham (1935) in cotton described extra-carpellary ovules due to hybridization. In *Beta vulgaris* Archimovitch (1931) described an open ovary cavity due to series of deformation. The presence of the ovules in the open stylar canal in the family Ulmaceæ has been explained to be a pathological phenomenon caused by insect parasites. Capoor (1937) explained the abnormalities in *Holoptelea integrifolia* because of the excessive growth of the funiculus. Any single cause cannot be assigned to the abnormalities described in *Peganum harmala*. However, in the "open carpel" case the opening of the loculus appears to be due to the disunion of the carpellary margin which has probably taken place due to the development of pollen sacs.

SUMMARY

Two abnormal gynoecia of *Peganum harmala* have been described. In the first an ovule on the filamentous prolongation of the ovary wall has been defined as "extra-locular abnormal ovule", besides this it has a glandular protuberance and a stamen which is confluent throughout the entire length of the ovary wall bearing five anther loculi.

The second gynoecium shows an "open loculus" bearing healthy and normal ovules termed as "gymnospermous". The term naked ovule and gymnospermous ovule are considered as synonymous. The open carpellary margin developed anther loculi which extend up to the stigma twisted on partially opened style.

The use of the term "naked" for ovules which are enclosed in angiospermic carpels, but have lost their integuments has been criticized and the term "extegmic" has been suggested as a better substitute.

ACKNOWLEDGEMENT

I thank Prof. B. Tiagi for guidance and to Dr. V. Puri, School of Plant Morphology, Meerut, for help given in connection with this investigation. Thanks are also due to Principal V. V. John and Government of Ajmer State for encouragement and award of a Research Scholarship.

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* Not seen in original.

ON THE ANATOMY OF *ALTERNANTHERA REPENS* (LINN.) O. KTZE.

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(Received for publication on July 28, 1955)

INTRODUCTION

THE anatomy of several species belonging to the genus *Alternanthera* has been studied by various workers, viz., *A. spinosa* (Schleiden and De Bary, 1877); *A. procumbens* (Nemnich, 1894); *A. muscoides* (Solereder, 1908, p. 651); *A. aquatica* (Chodat and Rehfoos, 1924); *Alternanthera* sp. (Pfeiffer, 1926); *A. sessilis* (Joshi, 1931); and *A. Philoxeroides* (Metcalf and Chalk, 1950, p. 1071). The original literature regarding the species listed above was not accessible to the author, except the paper on *A. sessilis* by Joshi (1931). The comparisons with these species, therefore, have been restricted to the account given by Solereder (1908) and Metcalfe and Chalk (1950). This paper describes the anatomy of *A. repens* which is found to differ in several respects from the anatomy of the other species of *Alternanthera* investigated so far.

MATERIAL AND METHODS

The material was collected locally by the author and the observations have been made from the free-hand sections stained with safranin and mounted in glycerine.

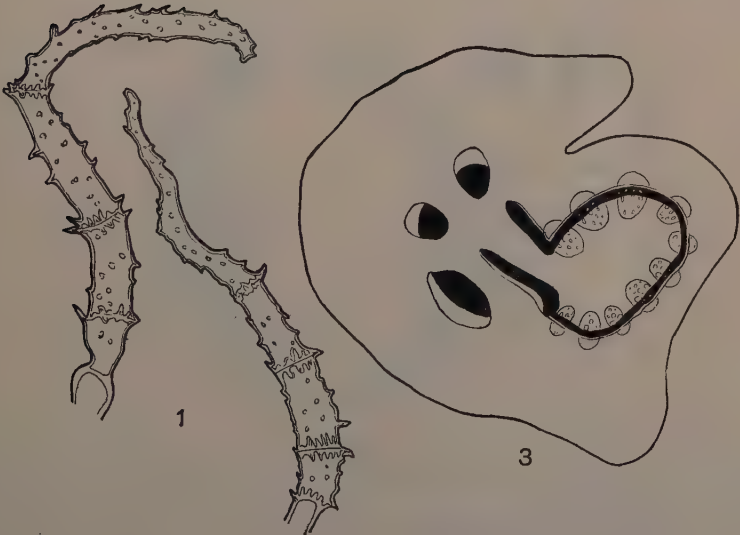
DISTRIBUTION

The species *A. repens* (Linn.) O. Ktze. (Syn. *A. achyrantha* R. Br., *A. echinata* Sm.) distributed in Florida, Central and South America was first introduced into India sometime in 1913 and has by now spread widely. The species has been observed growing wild at Coimbatore, Bangalore, Madras, Bombay, Delhi and Dehra Dun.* It has also been observed by the author growing profusely at Lucknow (U.P.), Santhal Parganas (Bihar) and Kalka (Punjab).

EXTERNAL MORPHOLOGY

Alternanthera repens is a prostrate, rapidly spreading profusely branched and loosely pilose herb, growing wild in dry and waste places. The stem is terete and without any grooves. Leaves spatulate or obovate to oval or suborbicular 2 cm. long or less, pinnately veined, obtuse or abruptly tipped, narrowed at the base into short petioles. The adventitious roots grow abundantly from the lower nodes of both the main stem and the branches.

* From a personal communication from Dr. H. S. Rao, Officer-in-Charge and Systematic Botanist, Botany Branch, Forest Research Institute, Dehra Dun.

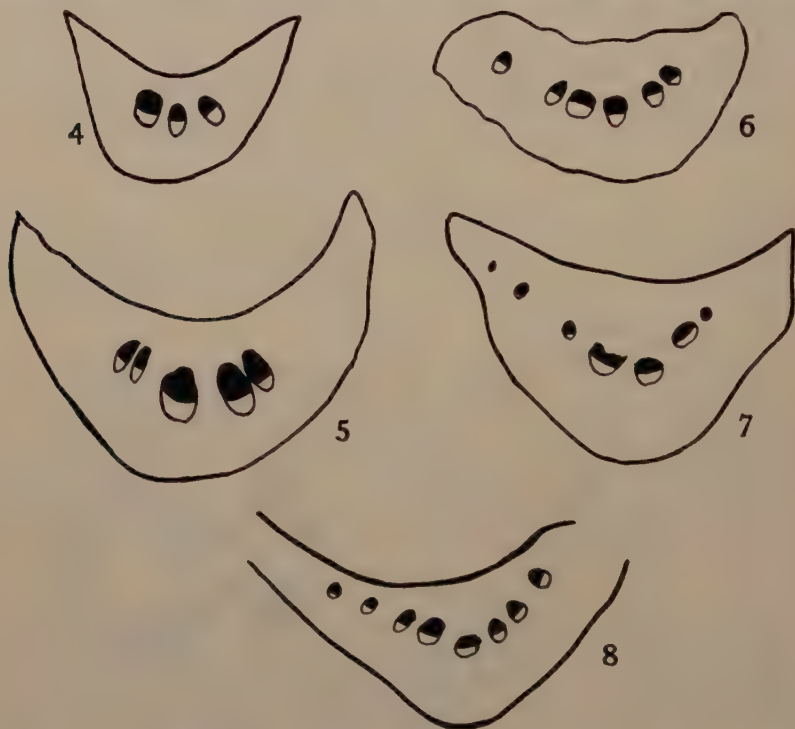


FIGS. 1-3.—Fig. 1. Hair showing a single basal cell, papillæ and the interlocking crosswalls, $\times 225$. Fig. 2. A part of the cuticle from the upper surface of the leaf showing wavy-walled epidermal cells and the stomata, $\times 225$. Fig. 3. A cross-section through a node with the three petiolar strands at the base of the petiole, $\times 34$.

ANATOMY

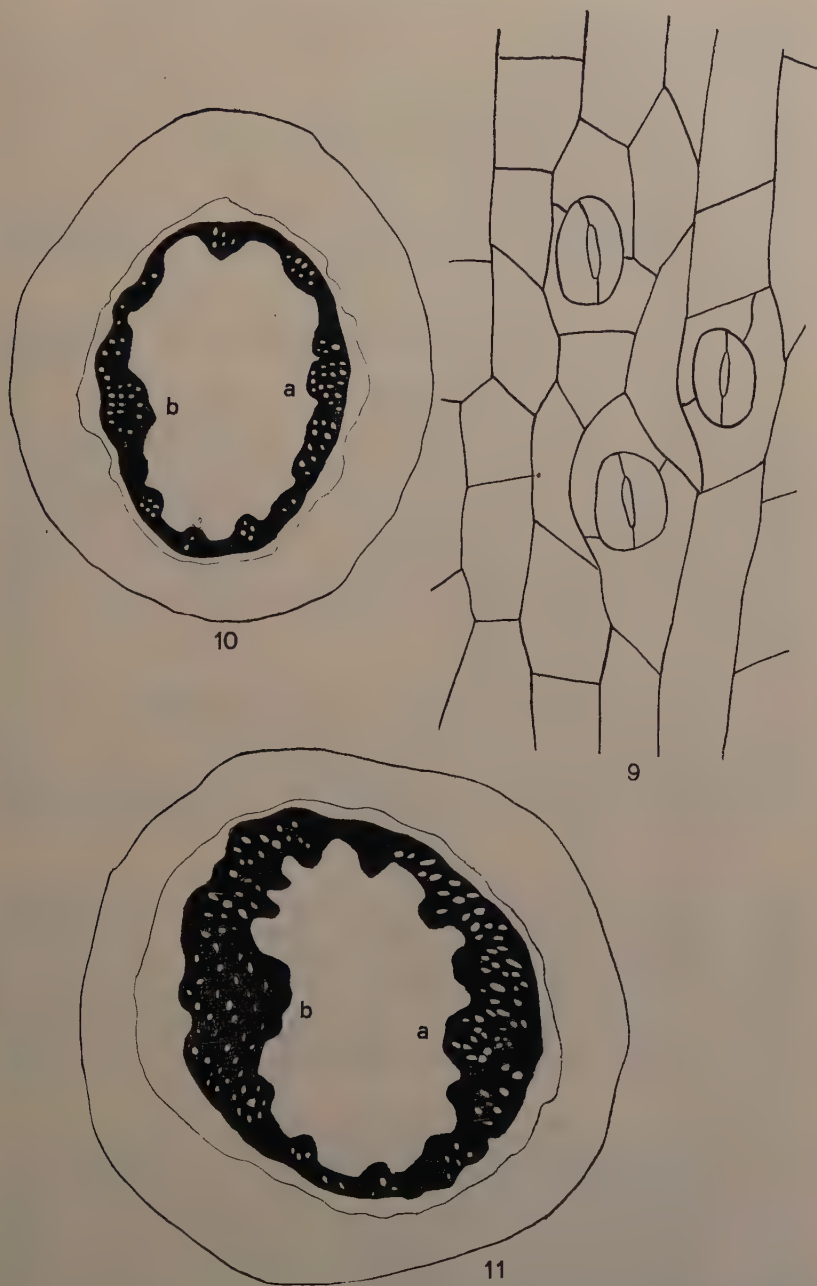
Hairs.—The hairs are uniseriate, multicellular composed of more or less interlocking cells, the basal cell single and short while the apical cell is long pointed (Fig. 1). The surface of the hairs bears short to slightly longer papillæ. The hairs are very much similar to those of *Aerua lanata* (Solereider, 1908, p. 652, fig. 156 C), but for the basal cell which is single in *A. repens*.

Leaf.—The walls of the epidermal cells are wavy on both the upper and the lower surfaces of the leaf (Fig. 2). The leaves are amphistomatic, stomata comparatively abundant on the lower surface. The mesophyll consists of spongy and palisade tissue and there is no aqueous tissue in the leaf in spite of their apparently fleshy appearance.



FIGS. 4-8.—Figs. 4-7. Cross-sections through the petiole from between base to apex showing the increase in number of the vascular strands, $\times 26$. Fig. 8. A cross-section through the midrib showing the eight vascular strands, $\times 26$.

There are three vascular strands (Fig. 3) which enter the base of the leaf. The number of the vascular strands increases from 3-6 or



FIGS. 9-11.—Fig. 9. A part of the cuticle from the stem showing a stomatiferous region, $\times 225$. Figs. 10-11. Cross-sections through the upper internodes showing the absence of the medullary bundles and the excessive secondary activity at two opposite regions, *a* & *b*, $\times 34$.

7 (Figs. 4-7) in the petiole and 6-8 strands are noted in the midrib of the leaf (Fig. 8).

The vascular bundles of the veins and their fine ramifications are surrounded by large and cubical parenchymatous cells. Clustered crystals have also been found in mesophyll as well as in cortex.

Stem.—The epidermal cells of the stem (Fig. 9) are very much elongated and straight-walled. Stomata generally occur in groups of 3-5 and these groups are scattered all over the stem. The epidermal cells in the stomatiferous regions are comparatively much shorter than the cells in the non-stomatiferous regions.

The epidermis is followed by 2-5 layers of collenchyma. The cortex is made up of more or less loosely arranged cells. Chloroplasts are present in the cortical cells.

The number of the primary bundles in an apical internode is eight as in *A. sessilis* (Joshi, 1931, p. 217). All the vascular bundles are equidistant from the centre of the stem. The stem only possesses the ordinary ring of the vascular bundles and the medullary bundles are absent (Figs. 3, 10 and 11). The absence of the medullary bundles has also been observed from the nodes and internodes of the older stems.

The first complete vascular cylinder is formed as in normal dicotyledons. The cambial ring does not remain uniformly thick all round. It shows enormous secondary activity at two opposite regions in the stem (Figs. 10-11).

The supernumerary cambiums are found developed at the basal regions of the stem and are found to be formed the same way as in *Alternanthera sessilis* (Joshi, 1931, pp. 221-24).

Root.—The structure of the primary and the adventitious root and its secondary growth are as described in *A. sessilis* (Joshi, *l.c.*, pp. 224-27).

DISCUSSION

The anatomy of *Alternanthera repens* differs in several respects from the anatomy of the other species described so far. In some of these characters it resembles the anatomy of the other genera in *Amarantaceæ*. The most distinctive feature of anatomy noted in *A. repens* is the complete absence of medullary or pseudo-medullary bundles from the stem. In other species of *Alternanthera* the medullary bundles are present (Solereder, *l.c.*; Metcalfe and Chalk, *l.c.*; Joshi, *l.c.*).

The hairs in *A. repens* are also different from the hairs of the other species. In *A. repens* the hairs are papillose, uniseriate trichomes. In *A. spinosa* (Schleiden and De Bary, 1877, *cf.* Solereder, 1908, p. 653) candelabra type of hairs (Solereder, 1908, pp. 651-53, fig. 156 D) are found. Capitate type of hairs are found in some species of *Alternanthera* (Nemnich, see Solereder, *l.c.*, p. 653). Simple multicellular unbranched hairs have been reported in *A. sessilis* (Joshi, 1931, p. 216). Papillose uniseriate hairs are also not uncommon in the genus *Alternanthera* (Solereder, *l.c.*, p. 653, foot-note).

The cell walls of the epidermal cells of the leaf are wavy in *A. repens*, while in *A. sessilis* they are straight (Joshi, *l.c.*, p. 216).

The stomata on the stem are arranged all round in groups of 2-5 surrounded by shorter cells. The epidermal cells in the region devoid of stomata are several times longer. In *A. sessilis* the stomata on the stem are located in two grooves only (Joshi, *l.c.*).

The number of the vascular strands in the petiole and midrib of the leaf of *A. repens* is more than three while in *A. sessilis* there are three vascular strands in the petiole and the midrib (Joshi, *l.c.*). In this respect *A. repens* differs from *A. sessilis*, but resembles *Achyranthes*, *Cyathula* and *Pupalia* (Joshi, 1931 a) and *Amaranthus*, *Frælichia* and *Gomphrena* (Metcalf and Chalk, 1950, p. 1069, fig. 256 GHK).

Another interesting feature of anatomy noted in *A. repens* is that the vascular bundles of the large and smaller veins including their ultimate ramifications are surrounded by a sheath of large and cubical parenchymatous cells as already reported in *A. muscoides* (Solereider, 1908, p. 651). Nothing is known about this feature in *A. sessilis*. A similar feature is noted in various species of *Amaranthus* and *Gomphrena* and in *Phloxerus vermicularis* (Solereider, *l.c.*). The presence of a sheath made of large cubicular cells and enclosing the vascular bundle is a character of common occurrence among the monocotyledon and is rather rare in the dicotyledon (Solereider, *l.c.*, p. 651).

In the presence of the kind of crystals in mesophyll and the other tissues *A. repens* differs from other species of the genus *Alternanthera*. In *A. repens* clustered crystals are found both in mesophyll and cortex. Solitary crystals are known to occur in *A. procumbens* (Nemnich, 1864, see in Solereider, *l.c.*) and crystalloids in the other species of *Alternanthera* (Metcalf and Chalk, 1950, p. 1069).

The anatomical study of *A. repens* in comparison with the other species of *Alternanthera*, therefore, shows that certain distinct anatomical characters distinguish *A. repens* from other species. These characters taken together, *viz.*, the papillose hair, wavy-walled epidermal cells, more than three vascular bundles in the petiole and midrib and the clustered crystals in mesophyll and cortex and the absence of medullary bundles in the stem, etc., can be reliably employed in separating *A. repens* from the other species of *Alternanthera*.

SUMMARY

The anatomy of *A. repens* recently introduced into India has been studied. The species differs from the other species of *Alternanthera* in papillose, hairy trichomes; absence of medullary bundles in the stem; in wavy-walled epidermal cells of leaf; 5-6 strands in petiole and midrib and the clustered crystals in mesophyll and cortex.

It is suggested that the variety of anatomical characters in the genus *Alternanthera* may be employed together with other morphological characters to distinguish various species in the genus.

My thanks are due to Dr. A. C. Joshi for a critical reading of the manuscript.

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STUDIES IN POLYPODIACEÆ. III. *LOXOGRAMME* (BL.) PRESL.

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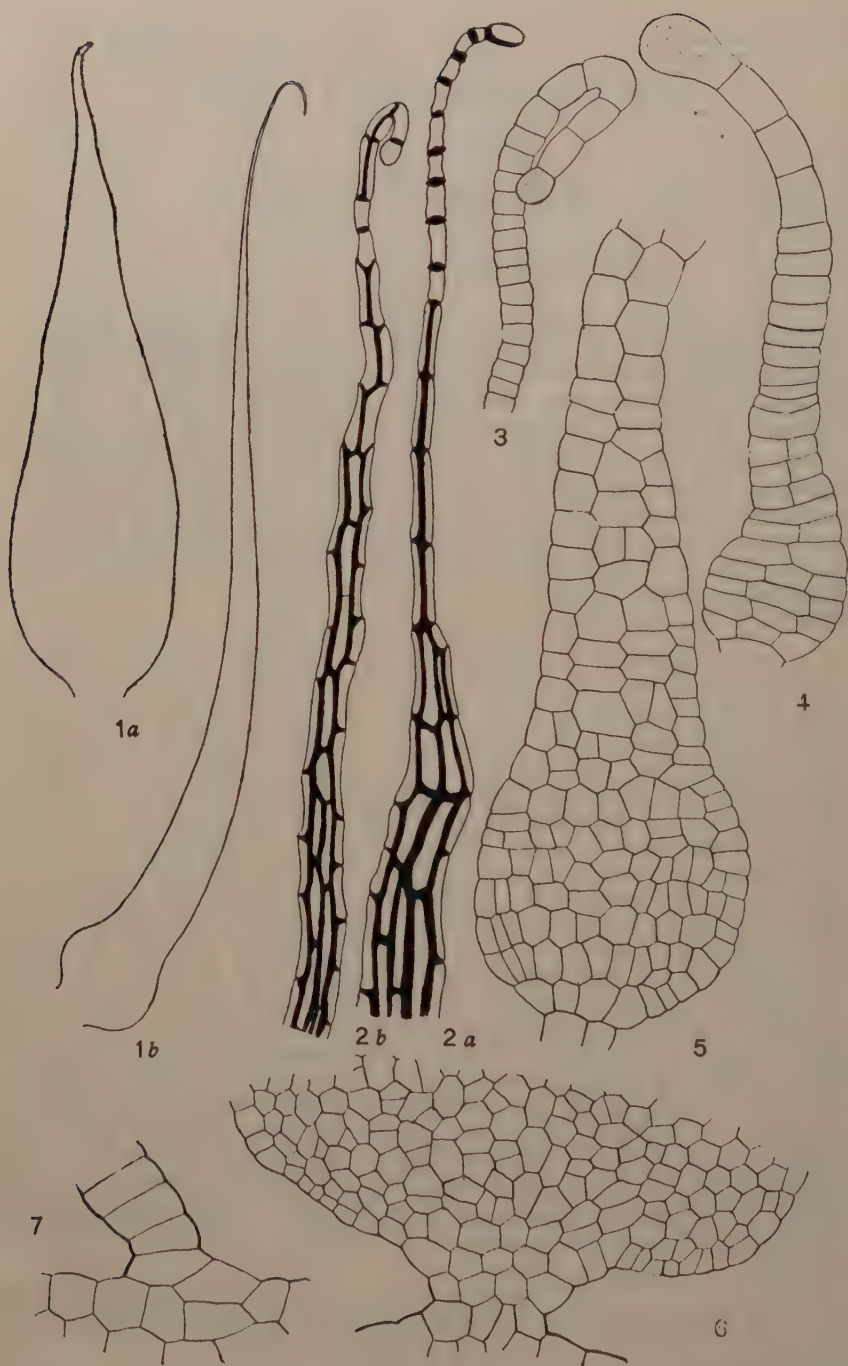
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(With 26 Figs. in the Text)

Loxogramme (Bl.) Presl. is a tropical epiphytic genus of about 35 species, typified by *L. lanceolata* (Sw.) Presl. The present study is based on the type species and *L. involuta* (Don.) Presl. from the forests of K. & J. Hills (Assam), growing on shaded regions of tree trunks attached by spongy masses of roots entangled among the epiphytic mosses and liverworts. The former species is rarer and has been found restricted to the denser regions of the forest where the moisture content of the substratum is higher and the tree trunks are eternally shielded from direct sunlight by the heavy canopy of giant trees and lianas. Methods followed in study of both the sporophyte and the gametophyte are the same as described earlier (Kachroo and Nayar, 1953; Nayar and Kachroo, 1953; Nayar, 1954).

The rhizome is moderately thick (generally 1.0 cm. thick in *L. involuta* and 0.5 cm. thick in *L. lanceolata*), fleshy, short, branched and covered by felts of roots. Paleæ are clathrate, lanceolate (Figs. 1 *a* and 1 *b*) with a long attenuate hair-like tip ending in a prominent gland cell (Figs. 2 *a* and 2 *b*) and attached by a narrowed base. Near their attachment rhizoides occur in abundance over the rhizome especially in case of paleæ on the surface near the substratum. Paleæ originate as thick long uniseriate hairs in which the terminal cell soon becomes swollen as a prominent yellowish gland (Fig. 3). The lowermost cell remains as a unicellular stalk while cells next to it divide by vertical walls bringing about flattening (Fig. 4) which is more prominent towards the stalk so that the narrow short stalk is clearly marked off from the ovate base of the main body of the palea (Figs. 5 and 6). The stalk cell also divides later to form the 4 to 5 cells broad stalk (Figs. 5 and 6), remaining one cell thick as is the main body of the paleæ (Fig. 7). No lateral or superficial glands are formed at any stage in development and the glandular tip is usually shed off at maturity. Paleæ are borne superficially on the epidermis and do not pierce it. The epidermal cells of the rhizome are parenchymatous and smaller than the cortical cells. The ground tissue is entirely parenchymatous with silvery walls and deposits of starch (except in the outer cortical cells). Three or four layers of cells surrounding the endodermis of vascular bundles in *L. involuta* are slightly thick-walled.

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FIGS. 1-7. Paleæ.—Fig. 1a. *Loxogramme involuta*, $\times 10$. Fig. 1b. *L. lanceolata*, $\times 20$. Fig. 2a. Apex showing terminal gland: *L. involuta*, $\times 50$. Fig. 2b. Same: *L. lanceolata*, $\times 50$. Fig. 3. Early stage in development: *L. lanceolata*, $\times 75$. Fig. 4. Initiation of flattening: *L. involuta*, $\times 120$. Fig. 5. Differentiation of stalk: *L. involuta*, $\times 120$. Fig. 6. Basal region of young palea, $\times 75$. Fig. 7. Vertical l.s. of base showing attachment to rhizome, $\times 50$. *p*, base of palea; *rh*, rhizome epidermis.

Endodermis in both the species lack the usual type of thickening of inner walls.

The vascular cylinder is a "false dictyostele" as in majority of Polypodiaceæ (Figs. 8 and 9) and the individual bundles have the same general structure (Nayar, 1954). Number of vascular bundles are fewer in *L. lanceolata*. Leaf traces are alternate on the upper surface of the rhizome. In *L. lanceolata* the dorsal median vascular bundle gives off leaf traces alternately on either side, assisted in each case by the lateral vascular strand on the side the trace is formed. Generally three bundles, two bigger adaxials and one smaller abaxial, constitute a leaf trace, one of the adaxials and the abaxial originating as branches of the median bundle of the rhizome while the other adaxial originates as a branch of the lateral bundle. Preceding each leaf trace the median vascular bundle (Fig. 9, *m vb.*) exhibits complicated divisions and fusions. Branch traces in *L. lanceolata* are not associated with leaf traces but are formed by one of the main vascular bundles of the rhizome nearest the branch diverging outwards and entering it. In *L. involuta* where leaves are bigger and the stelar cylinder of rhizome is composed of larger number of vascular strands, the leaf traces are more complicated, especially so due to association of branch traces with them. The median dorsal vascular strand of *L. lanceolata* is represented by two or three separate vascular strands which branch and form complex vascular plexuses preceding each leaf. Two or more of the lateral vascular strands of the rhizome lying adjacent to the median bundles branch and proceed outwards as the abaxial strands of the leaf trace. A branch of one of the median bundles constitute the prominent adaxial strand on one side while the other is formed by a main lateral vascular bundle of the rhizome curving outwards. Leaf gaps are mended before trace to next leaf originates. Each leaf trace in *L. involuta* consists of 6 to 10 strands of which the adaxial ones are thicker. No mechanical tissue accompanies the leaf traces. A branch trace (Fig. 9, *br.*) is formed on the abaxial lateral surface of each leaf trace and is a single strand as in *L. lanceolata*, but originating as a branch of one of the vascular bundles of the rhizome which soon divides and forms part of the leaf trace. Most of the branches in either species remain dormant. Root traces are given off indiscriminately from the lower and lateral bundles of the rhizome as small superficial branches. These, on reaching the outer cortex, develop a sclerenchyma sheath, first on the surface facing the outside of the rhizome.

Leaves are subsessile, simple and entire, oblanceolate in *L. involuta* and linear in *L. lanceolata*. They are non-articulate to the rhizome but a saucer-shaped abscission pad with the convex surface protruding

into the rhizome is developed by older leaves at the extreme base before shedding. Leaf scars are deep hollows often showing protruding remnants of vascular bundles and lined by black, dead parenchyma cells. The leaf lamina is thick, leathery and glaucous and possess

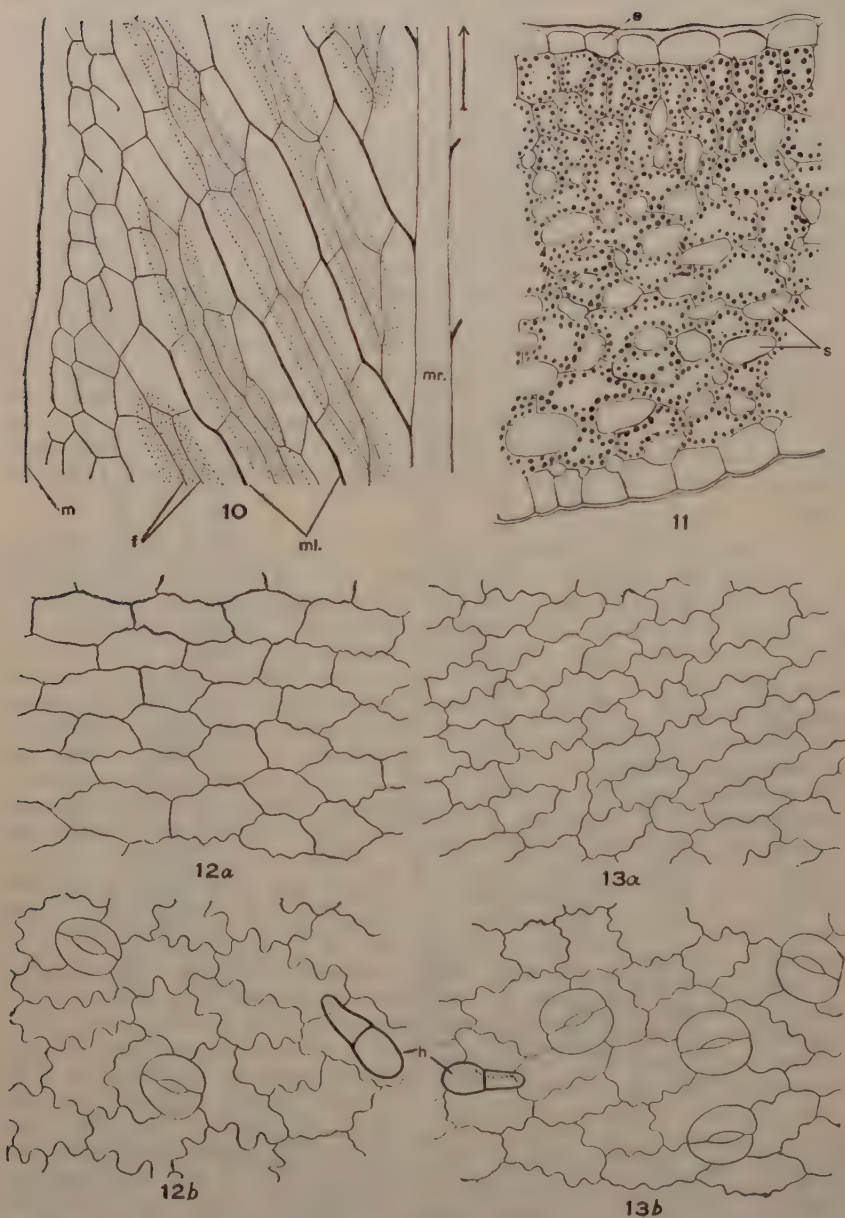


FIGS. 8-9. Vascular system of a portion of rhizome reconstructed from serial transverse sections (the arrow points to the apex of the rhizome). Fig. 8. *L. involuta*, $\times 10$. Fig. 9. *L. lanceolata*, $\times 10$. *m.v.b.*, median vascular bundle; *lt.*, leaf trace; *br.*, branch trace; *D*, dorsal surface of rhizome.

a cartilaginous margin. The midrib is prominent while the lateral veins and their ramifications are immersed. Venation (Fig. 10) is reticulate with highly oblique and closely placed main lateral veins,

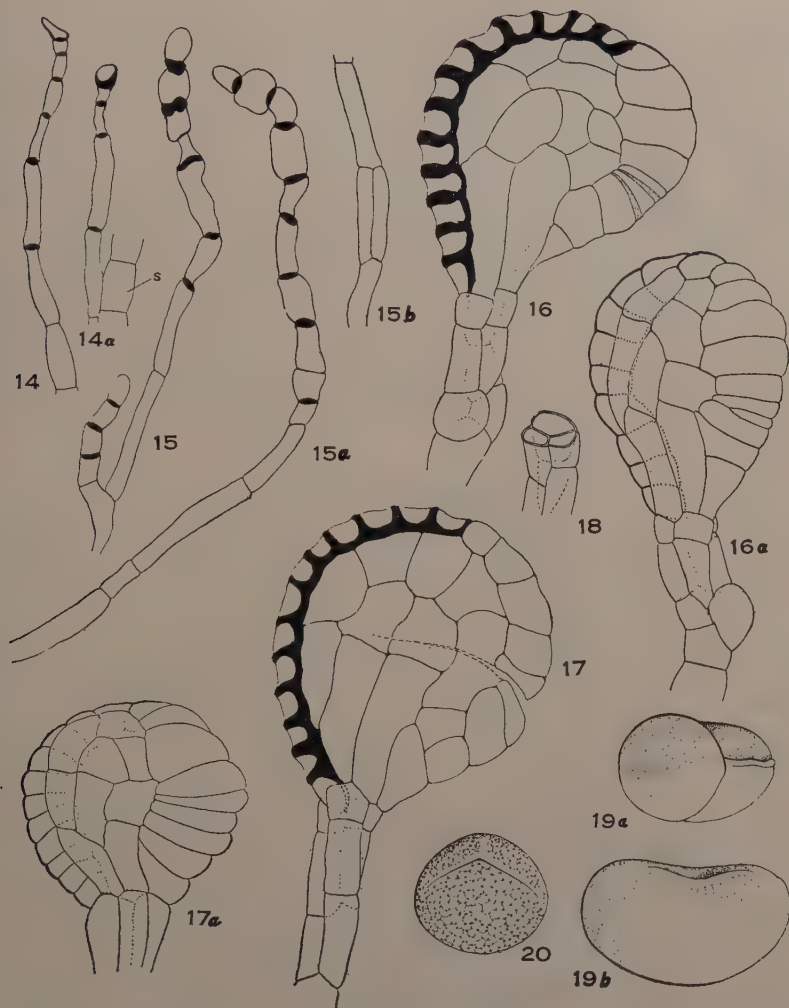
which arch upwards slightly and lose their identity towards the margins. The lateral veins bear secondary veins which branch and form 2 to 3 rows of hexagonal æreolæ elongated parallel to the main lateral veins. Towards the margins 2 to 3 rows of æreolæ are smaller, more or less regular and sometimes elongated parallel to the leaf margin. Free unbranched veinlets occur included rarely in the meshes. No regular intramarginal vein is formed. The lamina is thick (Fig. 11) with the outer walls of the epidermal cells (especially on the upper surface) thickened. Mesophyll is undifferentiated and is formed of armed parenchyma. The hypodermal layer on the upper surface is slightly columnar and cells are not armed. Cells of the upper epidermis have a more or less regular contour in surface view in *L. involuta* (Fig. 12 *a*) while it is wavy in *L. lanceolata* (Fig. 13 *a*). Lower epidermis is similar but with more irregular outline (Figs. 12 *b* and 13 *b*). Stomata are restricted to the latter; the epidermal cells subtending them are similar to other epidermal cells and surround only the lower one-third of stomata. Brownish hairs each with an apical ovate cell with dense contents and a narrower stalk cell occur sparsely distributed on the lower epidermis in both species (Figs. 12 and 13, *h*).

Fertile leaves are similar to sterile ones except for slight decrease in breadth in some cases in *L. involuta*. The apical half alone of some leaves in this species may be fertile and in such cases the fertile region is slightly contracted. Sori are prominent and elongate, parallel to the main lateral veins, one equidistant between each pair. Two rows of sori, one on each side of costa, occur per leaf. Each sorus is subtended by a pair of closely placed parallel tertiary veins interconnected at intervals and originating from the first secondary vein connecting the primary lateral veins near the midrib. The fertile veins are connected to the main lateral veins on the respective sides by secondary veinlets, forming a regular row of æreolæ. Sporangia occur all over the fertile veins and the leaf surface between them. In all cases the sorus falls short of the margin where fertile veins merge into the general reticulum. (The lateral veins being highly inconspicuous in the thick lamina of *Loxogramme* it is difficult to observe the fertile veins without special treatment even in the fresh leaves, especially so as the placentæ of sori are with dense, coloured contents.) The placentæ may either be flush with the leaf lamina or protrude as a cushion. Sporangia occur mixed with paraphyses in both species. The paraphyses are long filamentous hairs with elongated superimposed cells having the transverse walls thickened like a biconvex lens and becoming brownish at maturity. They are thin and tapering towards the apex in *L. involuta* (Fig. 14) and occur rarely attached to the basal stalk cell of the sporangia (Fig. 14 *a*). In *L. lanceolata* paraphyses are more prominent and have the penultimate cell at the apex swollen, becoming globular in some cases. Rarely a single basal cell may bear two paraphyses (Fig. 15 *a*) and exceptional cases of longitudinal division of some cells of the basal half also occur (Fig. 15 *b*). Lens-shaped thickenings of the cross-walls occur only in the upper half of the paraphyses and these regions are deciduous, being shed off early.



FIGS. 10-13. Leaf morphology.—Fig. 10. Portion of lamina of *L. involuta* showing venation and position of sori, $\times 13$ (shaded regions represent sori and the arrow points to the apex of the leaf): *f*, fertile veins; *m*, margin of leaf lamina; *ml*, main lateral veins; *mr*, midrib. Fig. 11. T.s. portion of lamina: *L. lanceolata*, $\times 130$; *e*, upper epidermis; *s*, air spaces. Figs. 12 & 13. Surface view of

foliar epidermis, $\times 110$. Fig. 12a. *L. involuta*: upper epidermis. Fig. 12b. Same: lower epidermis. Fig. 13a. *L. lanceolata*: upper epidermis. Fig. 13b. Same: lower epidermis; h, hair.

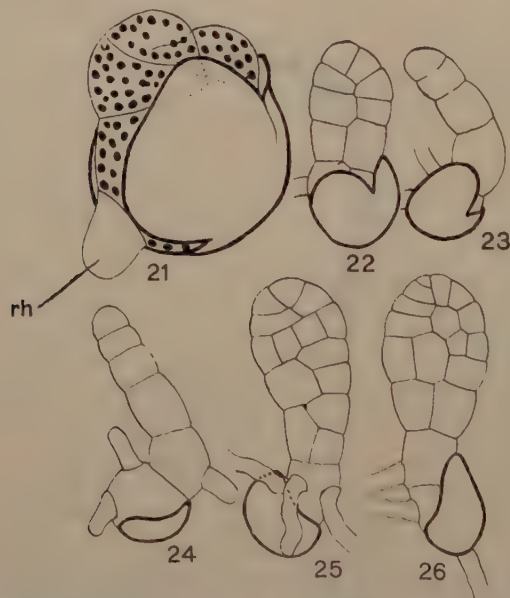


FIGS. 14–20. Soral morphology.—Figs. 14 & 14a. Paraphyses of *L. involuta*, $\times 50$; s, sporangial stalk. Figs. 15, 15a & 15b. *L. lanceolata*, $\times 50$. Fig. 16. Mature sporangium of *L. involuta*, $\times 130$. Fig. 16a. Young sporangium of same showing three-rowed stalk, $\times 130$. Fig. 17. Mature sporangium of *L. lanceolata*, $\times 130$. Fig. 17a. Young sporangium of same, $\times 130$. Fig. 18. Upper region of sporangial stalk of *L. involuta*, $\times 130$. Figs. 19a & 19b. Spores of *L. involuta* in two views, $\times 320$. Fig. 20. Spore of *L. lanceolata*, $\times 320$.

(This deciduous nature of the upper regions and the close resemblance of the lower regions to sporangial stalks might possibly have led to

the current confusion regarding the occurrence of paraphyses in the genus.)

The sporangia are long-stalked and of the polypodiaceous type (Figs. 16 and 17). The stalk is two-cells thick except at the top where it is three-celled (Fig. 18) and the extreme base which is one-celled. In very young sporangia the stalk is two-cells thick at the top. The annulus is differentiated laterally as a continuation of one of the stalk cells. The basal cell on one side of the sporangial wall protrudes downwards during segmentation and forms the third row clasping the upper region of the stalk as in sporangia of *Aspleniaceæ* (Wagner, 1952). The annulus is about 13 cells long and abuts on the stalk. Stomium is 4 to 6-celled with prominent lip cells and separated from annulus and stalk by unthickened wall cells. Spores are *ca.* 40 to 48 per sporangium and golden yellow in colour. They are bean-shaped with a prominent scar on the concave side in *L. involuta* (Figs. 19 *a* and 19 *b*) and globose tetrahedral tending to be elliptic with a triradiate mark having two long, straight and one inconspicuous arms (Fig. 20). An episporium is absent in both the species and the exine is smooth in *L. involuta* while it has obscure, irregular reticulations in *L. lanceolata*.



FIGS. 21-26. Spore germination in *L. involuta*.—Fig. 21. Germinating spore showing two germ papillae, $\times 200$; *rh*, rhizoid. Figs. 22-26. Stages in development of prothallus, $\times 75$.

The spores germinate readily in cultures and retain their viability for more than two years. The exine breaks at the region of the scar and the intine protrudes out as the germ tube (Fig. 21). In *L. involuta* the germ tube originates towards one end of the spore while

the first rhizoid pushes out through the other end. In cultures the rhizoids are slightly brownish in colour and usually possess a slightly enlarged base. More than one germ tube may be formed per spore (Fig. 21). The germ tube under optimum conditions grows into a filament 2 to 3 cells long, each cell being broader than long. Soon longitudinal divisions set in, initiating flattening. In crowded cultures and under insufficient light the filament may grow longer (Figs. 22 and 23). All cells including the basal cell enveloped by the exine of the spore undergo longitudinal divisions and take part in flattening (Fig. 24). An obconical apical cell is soon established (Figs. 25 and 26) and by its activity a cordate prothallus is formed in the usual way. During growth the single apical cell becomes replaced by an apical meristem lodged in the apical notch. The mature prothallus is cordate, broader than long and about 0.5 cm. broad generally. Trichomes of all types are absent. Sex organs are of the usual leptosporangiate type (Kachroo and Nayar, 1953) and occur mixed in early stages of development.

DISCUSSION

The genus *Loxogramme* (Bl.) Presl. has always been a problem to pteridologists. No two authors seem to hold the same view regarding its phylogeny so that the genus is notorious for its ambiguous systematic position. Christensen (1938) associates *Loxogramme* with his pleopeltoid ferns with the comment that it has "very doubtful relationship" and is "perhaps related to *Grammitis*", but in vegetative characters not unlike "*Hymenolepis* Kaulf. (*Belvisia* Mirbel) and *Paltonium* Presl." Copeland (1947 and 1951) goes a step ahead regarding *Loxogramme* as a Grammitid derivative under his Polypodiaceæ. (Later, in 1952, he has raised Grammitid ferns to family status.) In his opinion there is "no reason to doubt that *Loxogramme* is derived from *Grammitis*" and the distinctive type of venation developed as a consequence of enlargement of the leaf lamina is the only point of distinction with the latter genus. Holttum (1948) comments: "Copeland associates *Loxogramme* with grammitid ferns, but I suggest that it is much more probably an aberrant member of the present family" (Polypodiaceæ-Polypodioidæ, *sensu* Holttum). The most daring of all are the views of Ching (1940) who raises the genus to family status (Loxogrammaceæ Ching) regarding it as rather isolated and derived from a Gymnogrammeoid stock along with his Atrophyaceæ and Vittariaceæ. According to him the genus is "unnaturally associated with polypodioid ferns, from which it differs in several essential characters" (Ching, 1940, p. 234). Commenting on Ching's Polypodiaceæ, Copeland (1941) remarks: "Placing the Vittariaceæ near the Gymnogrammeoid ferns still surprises me.... My surprise grows to amazement when *Loxogramme* is elevated to family rank and appended to *Vittaria*. *Loxogramme* is Grammitid. There are hardly any two considerable genera of ferns whose relationship is more perfectly clear than that of *Grammitis* and *Loxogramme*" (Copeland, 1941, p. 163).

This confusion regarding phylogeny seems to a very large extent due to the peculiar blend of polypodiaceous and gymnogrammeoid features in *Loxogramme*. The highly disintegrated vascular system of the rhizome and the epiphytic habit of *Loxogramme* are shared by majority of Polypodiaceæ. Soral morphology tends to the Gymnogrammeoid phylum rather than to the Polypodioid though there is a superficial resemblance to the Grammitid. The sum-total of evidence from comparison of characters of minor importance, if regarded as pointing to a solution of the phylogeny, seems to suggest relationship to some of the earlier members of Copeland's Pteridaceæ like *Syngramma*, etc. The genus *Syngramma* J. Sm. is regarded as a Gymnogrammeoid by Ching and as a Lyndsæoid by Copeland. According to the latter *Syngramma*-line of evolution from *Lindsæa* has been effected by a loss of indusium followed by spreading of sporangia down the veins and eventually even into the intervening lamina. The simple stelar structure has undergone amplification by the development of a large pith, prominent overlapping leaf gaps and in some cases with further disintegration of the stele by secondary perforations. Trichomes became more prominent and in *Syngramma* is represented by 'black bristles'. The venation became—at least in some species—prominently reticulate. Through the different species of *Syngramma* starting with *S. pinnata* J. Sm. runs a tendency for simplification of the frond accompanied by development of a leathery lamina, a feature comparing favourably with Loxogrammoid and not commonly met with among Polypodiaceæ. The venation of simple leaves in *S. alisinifolia* (Pr.) J. Sm. (cf. Bower, 1928, fig. 735 d, p. 235) with costal, obliquely elongated, hexagonal æreolæ bordered by few rows of smaller marginal æreolæ ending in closed loops mixed with free marginal veinlets closely recalls venation of *Loxogramme*. The tendency to form secondary veinlets inside the costal æreolæ connecting the primary lateral veins is met with in Lindsæoid ferns like *Schizoloma ensifolia*, etc. The æreolæ are generally devoid of included veinlets in both. Venation of *Loxogramme* is more advanced in the same line than that of *Syngramma* in having secondary æreolæ inside the costal primary æreolæ and in having rare instances of open meshes sparsely distributed. The tendency for extension of sorus along veins and their spreading on to the lamina space adjacent to veins is further continued in *Loxogramme*. Instances of sori slightly elongated oblique to costa and occupying a position midway between margin and costa occur in some species like *S. pinnata* (see Copeland, 1947, pl. I A & B). This extension of sori has proceeded along the secondary veins parallel to the main lateral veins in *Loxogramme*. Aereolæ formed by pairs of fertile secondary veins being narrow, the sporangia with their Syngrammoid tendency to spread over the leaf surface, covered the intervening space forming a continuous cœnosorus. The vascular system of the rhizome also advanced a step further than that of *Syngramma* but in the same line. The tendency to form secondary perforations in the solenostele became more prominent resulting in a complete disintegration of the stele into a "false dictyostele", but the tendency of groups of vascular bundles to fuse into broad bands here and there in the rhizome (though followed by

disintegration) serves to connect the stelar form with that of *Syngramma*. It is interesting to note that though fusions occur among adjacent vascular bundles in Polypodiaceæ also, groups of vascular bundles fusing to form broad bands as in *Loxogramme* is not observed. Three separate vascular strands form a leaf trace in *Syngramma alsinifolia*, *S. borneensis*, etc. (Bower, 1928), as in *L. lanceolata*. The high degree of elaboration of the stele may account for the multiplicity of leaf traces in *L. involuta*, but the pattern of their formation remains the same. Generally in Polypodiaceæ where three separate bundles enter the leaf base (as in small-leaved species of *Pyrrosia*, etc.), the abaxial one invariably originates as a minor branch of one of the lateral bundles. But in *L. lanceolata* where too three bundles enter the leaf base the abaxial one originates separately, and is not a minor bundle compared to others, but by high degree of disintegration in petiole may become so.

Nature of paleæ on rhizome also lend support to a Syngrammoid affinity. The paleæ in *Syngramma*, etc., are described as small, 'with terminal bristles'. *Schizoloma ensifolia* Sw. also possesses similar bristle ending in a terminal gland. The long drawn out uniseriate tip of paleæ in *Loxogramme* topped by a glandular cell is similar to the paleæ in *Schizoloma ensifolia*, *Syngramma*, *Hemionites* L., etc. A glandular cell at the top of the paleæ characterises most of the Polypodiaceæ also but the terminal gland is accompanied by lateral glandular hairs, especially at the basal region (*Microsorium* Link, *Drynarioids*, etc.). Throughout the ontogeny of the paleæ in *Loxogramme*, *Hemionites arifolia*, *Schizoloma ensifolia*, etc., the margin remains smooth without any glandular development. The basal stalk-like region in *Loxogramme*, *Hemionites*, *Schizoloma*, etc., remains one cell thick throughout development and is flattened in the same plane as the main body of the paleæ. In Polypodiaceæ on the other hand the stalk becomes distinct and generally cylindrical and more than one cell thick. Even in cases like *M. pteropus* (Bl.) Copel. where the stalk is dorsi-ventrally flattened it becomes more than one cell thick.

The position of sori with respect to the venation has led to comparisons with Grammitid (Copeland, 1947, 1951) and Pleopeltid (Christensen, 1938) ferns. Sori in *Grammitis* are characteristically on the acroscopic veinlet on the adaxial surface of the main lateral veins, so much so that each main lateral vein has but one fertile vein associated with it. In *Loxogramme* in addition to one fertile vein on the adaxial side, each main lateral vein has another one on the abaxial side placed close to the fertile vein on the adaxial side of the main lateral next to it. But only one sorus is formed (by the sporangia covering both fertile veins and space between them) making the superficial resemblance to *Grammitis* striking. The formation of vascular connections between the fertile veins forming a pair gives a semblance to Pleopeltoid condition. But in the latter, sori are subtended by complex vascular plexuses as in *Belvisia* Mirbel.

The paraphyses in the sori form a second basis of comparison. In *Loxogramme* they are elongated, uniseriate, filamentous structures

originating rarely as branches from the lowest stalk cell of the sporangium, and frequently from the receptacle, a condition characteristic of *Syngramma*. The characteristic three-rowed stalk of sporangium, the average number of cells constituting the annulus, and the stomium with protruding lip cells and separated from stalk and annulus by unthickened cells, are also characters in common. It is interesting that the Lindsæoid group of ferns regarded as the ancestral types of *Syngramma* and relatives share with *Loxogramme* the unstable nature of the spores, both having globose tetrahedral as well as bean-shaped spores in different species of the same genus. Commenting on *Lindsæa*, Copeland (1947) has remarked: "Its spores are sometimes tetrahedral, sometimes bilateral but the naturalness of the genus is not questioned". The same view may be held regarding *Loxogramme* also.

The development and structure of the gametophyte offers little evidence of relationships. Our knowledge of Polypodioid gametophytes is so meagre that comparisons are well nigh impossible. But naked gametophytes are as a rule absent among Polypodiaceæ. Among Pteridaceæ, especially the Lindsæoid group, naked prothalli are the rule. The primitive feature of the gametophyte in having a very short germ filament becoming flattened as a whole goes well with the consideration of *Loxogramme* as Syngrammoid derivative.

Loxogramme may thus be safely regarded as a derivative of the Syngrammoid group, its resemblance to members of Polypodiaceæ Copel. being still another example of parallel evolution under influence of similar environment. The Syngrammoid group of ferns including *Loxogramme* are recent genera with restricted but common geographical range. Ching's consideration of *Loxogramme* (Ching, 1940) seems the most natural one, but with so close an affinity with the Syngrammoid ferns it need not be raised to family status. If on the plea of convenience Copeland's Pteridaceæ is to be maintained *Loxogramme* should belong there near to *Syngramma* than anywhere else.

SUMMARY

A phylogenetical evaluation of the morphological features of *Loxogramme lanceolata* and *L. involuta* is attempted. The plants are epiphytic on shaded tree trunks in the tropical forests of N.E. India and have an elongated fleshy rhizome clothed by superficial, clathrate, lanceolate paleæ attached by their contracted base. The rhizome is parenchymatous and vascular cylinder is a "false dictyostele". Leaf traces originate alternately from the upper surface and consist of three or more branches of the median and lateral vascular strands of the rhizome. Branching is common, the branch traces being single strands which in *L. involuta* are associated with leaf traces on the abaxial lateral surface. Leaves are simple, devoid of paleæ and articulation and with a thick leathery lamina having characteristic venation. Sori form a row on each side of the costa. Each sorus is elongated and is subtended by a pair of closely placed tertiary veins, each associated with the main lateral vein next to it. Sporangia occur mixed with

long, uniseriate, multicellular paraphyses. During development sporangial stalk becomes three-cells thick at top by the lower lateral wall cell on one side of the capsule growing downwards. Spores are globose tetrahedral in *L. lanceolata* and bilateral in *L. involuta*. Spore germination and development of gametophyte are as in Pteridaceæ. The germ tube is short and all cells take part in flattening. Mature gametophyte is cordate, with prominent midrib and devoid of trichomes. Sex organs are of the usual polypodiaceous type.

The affinities of the genus are discussed, and it is suggested that *Loxogramme* be considered as a Syngrammoid derivative and as such be included in Pteridaceæ Copel.

The major part of this work was done in the Botany Laboratory of the Gauhati University (Assam) and I am thankful to Prof. H. K. Baruah for all help he has rendered. Thanks are due to the Superintendent, Indian Botanical Gardens, Calcutta, for identification of the materials.

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STUDIES IN FLORAL MORPHOLOGY

II. Vascular Anatomy of the Flower of Certain Species of the Cactaceæ

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(With Sixty-eight Figures)

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INTRODUCTION

CACTACEÆ is a large family of about 124 genera and some 1,582 species, mainly distributed in dry districts of the warmer parts of America, especially of Mexico. So far there seems to be no detailed work on the floral morphology, especially the vascular anatomy of the flower of Cactaceæ. The systematic position of the family has remained controversial ever since its recognition by Linnæus. It has been assigned different places by different taxonomists. Moreover, Cactaceæ is one of the few polypetalous families with an inferior ovary, the nature of which in general, has been one of the most discussed topics in floral morphology. It was in view of these controversial problems concerning the family that Professor V. Puri suggested me to undertake a study of the vascular anatomy of its flower.

MATERIAL AND METHODS

Flowering material of *Pereskia bleo* and *Rhipsalis cassutha* preserved in 70% alcohol was very kindly sent to me by Mr. D. M. A. Jayweera, Superintendent, Botanic Gardens, Peradeniya, Ceylon; material of *Pereskia bleo* was also kindly supplied by Mr. J. Douglas, Curator, Botanic Gardens, Bogor, Indonesia. Flowers and buds of *Opuntia dillenii* and *Mammillaria tenuis* were collected respectively from plants growing in the Botanic Gardens of Government College, Ajmer and Agra College, Agra, and fixed in 70% alcohol.

Customary methods of microtechnique were followed. Serial transverse and longitudinal sections, 15–20 μ thick, were cut and stained with crystal violet and erythrosin. In every case hand-cut sections were also examined while several interesting features were made out by clearing whole buds with potassium hydroxide and lactic acid.

OBSERVATIONS

Pereskia bleo (HBK.) DC.

External Morphology of the Flower.—The flowers are pedicellate and borne in axillary and terminal clusters (panicles). The pedicels of the lateral flowers of a cluster are prominently reflexed rendering these flowers zygomorphic. The swollen receptacle is somewhat irregular in shape and bears 2–5 bracteoles which resemble ordinary foliage leaves except for their smaller size. The bracteoles have decurrent

bases so that the receptacle is vertically ribbed for some distance below each bracteole. Very often one or more bracteoles on the receptacle bear flowers in their axils—a fact recalling the homology of the receptacular cup encircling the ovary with the stem. There are about 20 tepals spirally arranged on the edge of the 'floral cup' (Jackson, 1934). The outer 4 or 5 tepals are small, tough and green (calyciform) while the innermost 5–7 are distinctly petaloid, being large, membranous and pink-coloured; the intermediate ones show all transitional stages. Thus the tepals form a perianth. But when the outer few tepals are compared with a few inner tepals, one is tempted to distinguish them as sepals and petals. This, however, is uncalled for, on account of the very gradual transition between the outer calyciform and the inner petaliform tepals. Such a view is also borne out by the fact that the vascular supply of all tepals, nay, even of the bracteoles, is built upon a fundamentally similar plan.

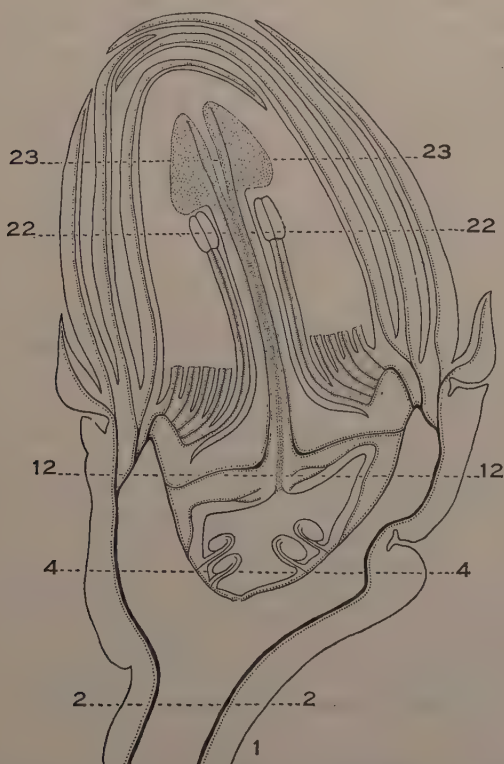


FIG. 1. *Pereskia bleo*.—Diagrammatic representation of a longitudinal section of a flower bud showing the origin of recurrent ring and vascular supply to different organs, $\times 7$.

The stamens are numerous and arranged spirally along the edge of the saucer-shaped receptacle inside the perianth. In the bud condi-

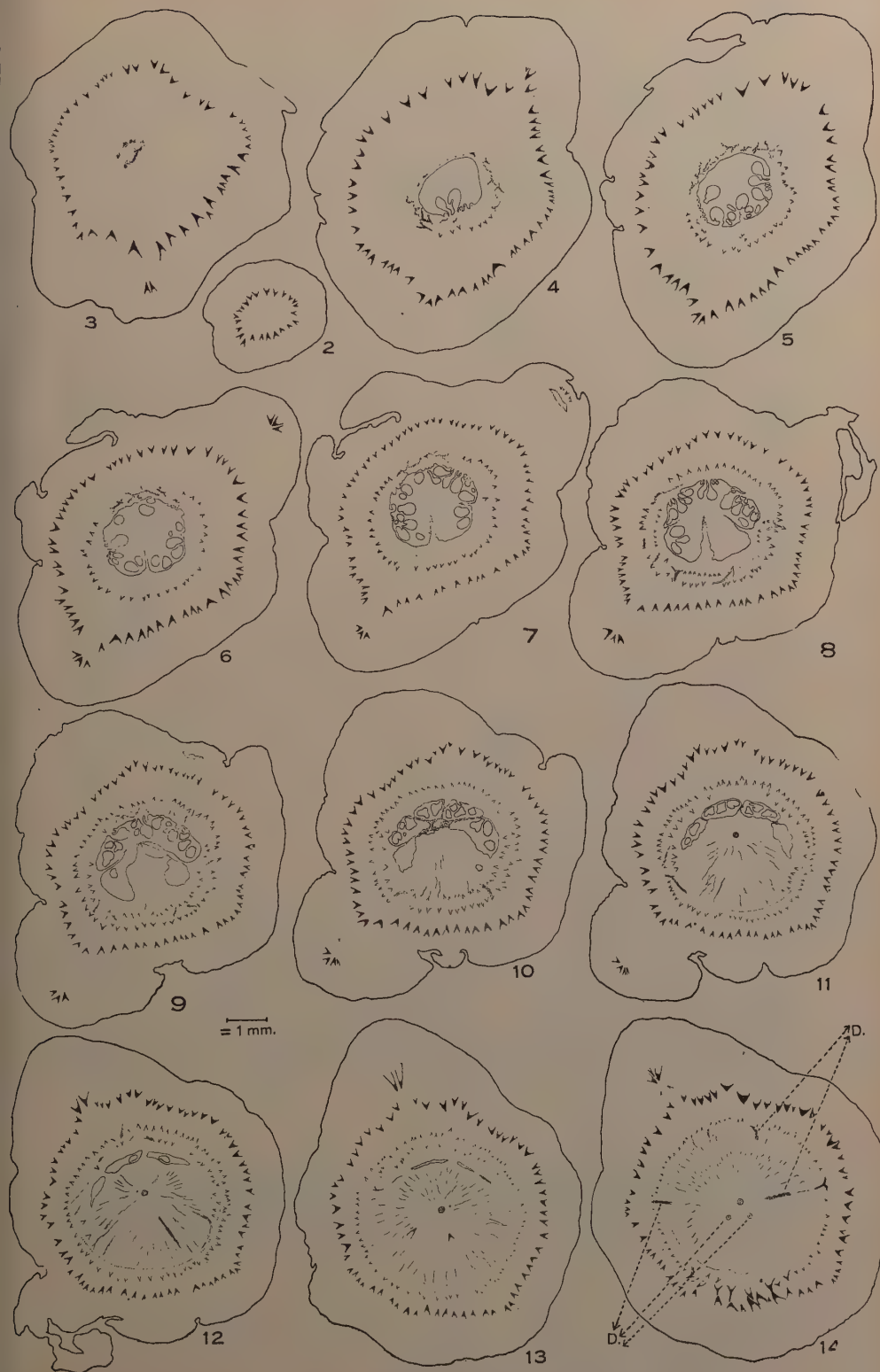
tion all the anthers are so compactly appressed to one another that in a section of the bud they all appear to be fused to form a single mass. The slender filaments are free and are shorter than the inner tepals. The style is long and crowned by 5-7 but most commonly 6 stigmatic lobes. The ovary is inferior, being completely embedded in the floral cup which widens out somewhat above the ovary. It is unilocular but becomes partitioned by outgrowths from the placental radii in the upper region (Figs. 12-16). The carpels are spirally arranged, a fact borne out by the successive appearance of the placenta (Figs. 4-8) and of the carpellary dorsals (Figs. 12-16). There are six parietal placenta, each bearing six rows of ovules (Figs. 4-8) which are anatropous and long-stalked.

Vascular Anatomy of the Flower.—The pedicel contains a much dissected siphonostele of about 18-25 conjoint vascular bundles (Fig. 2). As these bundles ascend higher in the receptacle, they divide repeatedly and diverge outward to form a more peripheral ring of numerous vascular bundles (Figs. 3-16). After reaching almost the top of the floral cup, these bundles give off the vascular supply of the perianth and the andræcium and then turn inward to descend down round the ovary. These are recurrent bundles (Smith and Smith, 1942 *a*) which are naturally inversely oriented (Figs. 1, 4-18). Soon after their bending down they set off six amphivasal bundles that diverge horizontally to enter into the style and continue up to the top of the stigmatic lobes (Fig. 1). Further down they give rise to small normally oriented bundles which traverse upward in the innermost region of the ovary 'wall'. Thus a transverse section of the ovary somewhere through the middle region exhibits three concentric rings of vascular bundles—an outer ring of normally oriented receptacular bundles, a middle ring of inversely oriented recurrent bundles and an innermost ring of rather minute, normally oriented bundles in the innermost portion of the ovary 'wall' (Figs. 8-13).

However, in the ovule-bearing regions of the placenta, the innermost bundles are not distinguishable from the recurrent bundles so that the ovular traces appear to be directly connected with the recurrent bundles. As soon as the ovule-bearing region of a placenta is finished, the innermost bundles start separating off from the recurrent bundles and constitute the third innermost ring of normally oriented vascular bundles (Figs. 1, 8-13). According to Sharma (1949) the bundles that enter the style (the dorsal bundles of the carpels) also arise from the innermost ring of vascular bundles. In the present material, however, they have been observed to be given off from the recurrent bundles just as they are bending down (Figs. 1, 14).

As soon as a placenta stops bearing ovules, an outgrowth consisting of densely staining cells, simulating transmitting tissue, proceeds towards the centre of the locule and fuses with similar outgrowths from other placenta in the centre making the ovary hexalocular in its upper region (Figs. 5-10).

The Bracteole.—The bracteoles receive their vascular supply from the outer ring of the receptacular bundles. Generally 2 vascular



FIGS. 2-14. *Pereskia bleo*.—Serial transverse sections of a flower bud from base upward. Fig. 2 shows the stele of the pedicel. Fig. 3. On the lower side two vascular bundles are diverging to supply a bracteole. Figs. 4-10 show the successive appearance and disappearance of the six placenta; hexalocular condition in Fig. 10. Figs. 11-14 show the successive disappearance of the locules and successive appearance of the carpellary dorsals. Fig. 14 shows the origin of three carpellary dorsals in the middle ring consisting of inversely oriented vascular bundles; on the lower side the bundles of the middle and outer rings are fusing.

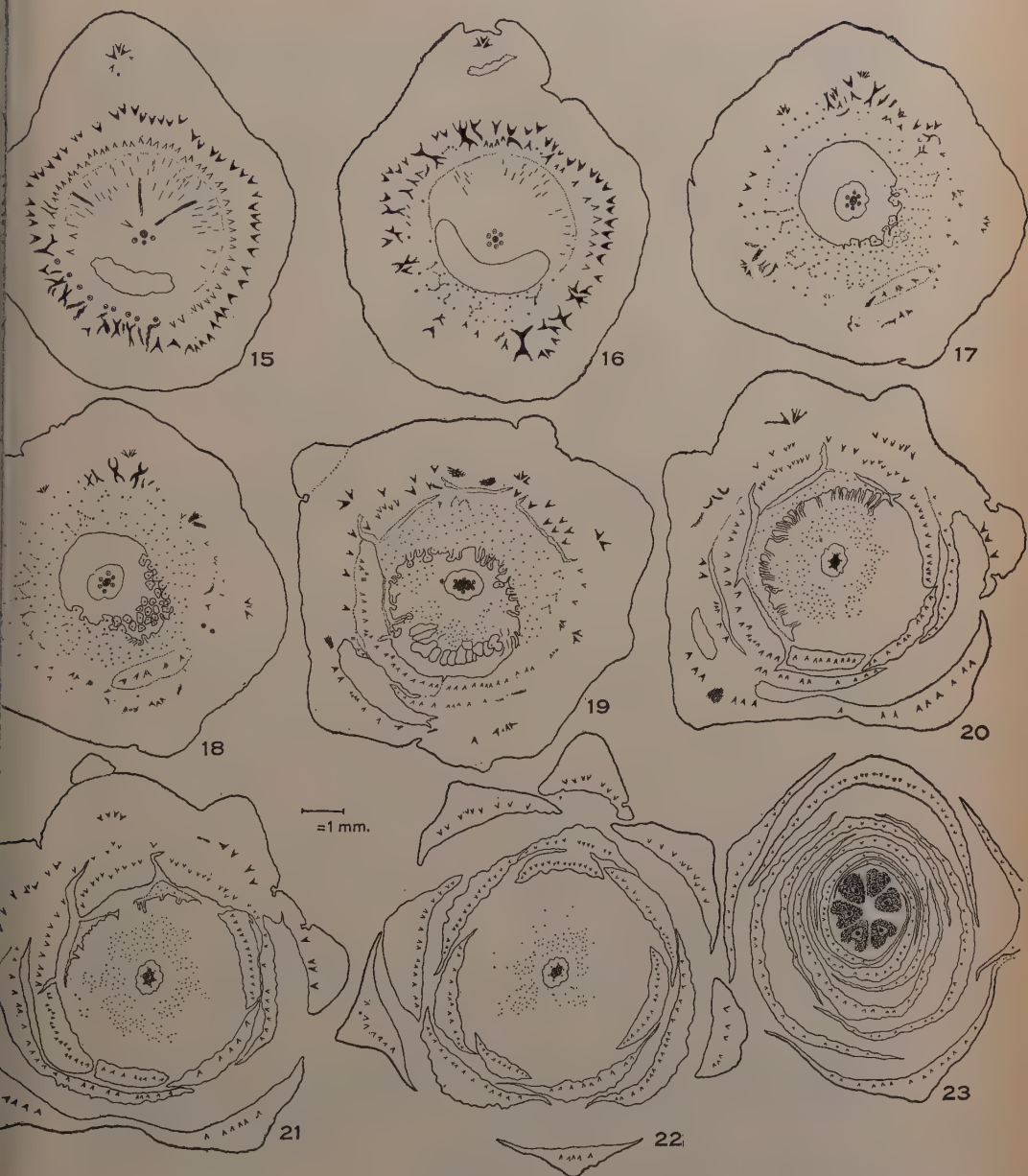
bundles separate off from this ring, traverse obliquely through the cortex for a fairly long distance (the bracteoles as already stated are decurrent) and branch one or more times, finally passing into the bracteole (Figs. 3-13). Here they divide further to form an arc of many collateral bundles, placed midway between the adaxial and abaxial surfaces of the bracteole. The vascular supply of the bracteole is very similar to that of a foliage leaf and recalls its homology with them. Each bracteole has numerous mucilage cavities which frequently separate one vascular bundle from another. The spiral phyllotaxy of the bracteoles is borne out by the fact that the vascular supply of two bracteoles never arise at the same level.

The Perianth.—The vascular supply of the tepals is given off from the receptacular bundles in their upper region, just before their bending down (Fig. 1). The number of vascular strands entering a tepal is not always constant. The outer few tepals receive one bundle each, which immediately divides into three bundles even before entering the tepal (Figs. 16-20). But the inner tepals receive several vascular bundles each. The vascular traces of the tepals exhibit both adnation and cohesion. Inside each tepal, the vascular bundles undergo repeated divisions to form an arc of numerous collateral bundles occurring through the breadth of the tepal nearer its adaxial surface (Figs. 20-23). This is in contrast with what is found in the bracteoles where the arc of vascular bundles lies midway between the adaxial and abaxial surfaces. Mucilage ducts, separating one vascular bundle from another are also found in the tepals.

The Andræcium.—The vasculature of the numerous stamens is a very interesting feature of the flower inasmuch as it exhibits adnation and cohesion of the vascular tissue in an extreme form. After the separation of the perianth traces, many amphivasal vascular strands are given off from the receptacular bundles. These are 'stamen fascicle traces' (Wilson, 1937) which divide several times and furnish one trace each to stamens on the same and adjacent radii (Figs. 1, 16-18). The single staminal bundle which is also amphivasal, traverses up to the top of the anther and remains unbranched throughout its course. Sharma (1949), however, reports branching of the staminal bundle once or twice in the anther region of *Pereskia aculeata*.

Opuntia dillenii Haw.

External Morphology of the Flower.—*Opuntia dillenii* is naturalised in several parts of India. The flowers are large, solitary and borne on the marginal and apical areoles of the flattened joints of the stem. The receptacle (hypanthium) is narrowly turbinate and bears areoles



FIGS. 15-23. *Pereskia bleo* continued.—Fig. 15. On the lower side the bundles of the middle and outer rings are meeting in pairs; several stamen fascicle traces have also appeared (in Figs. 16-22, each dot represents the vascular supply of a single stamen, filaments and anthers omitted). Fig. 23 shows the six stigmatic lobes.

on its outer surface similar to those on the young joints of the stem. The areoles are white, tomentose with scant glochids but without spines. Small cylindrical to subulate leaves (bracteoles) with a reddish tinge are also present on the areoles of the receptacle in the early stages of development but these are caducous. As in *Pereskia*, occasionally the bracteoles on the receptacle bear flowers in their axils so that two or more generations of fruits may be formed on a single plant during one season. On the top of the receptacle there is a cupular depression from the bottom of which arises the stout, rather columnar style crowned with 6-9 stigmatic lobes. The numerous stamens which are shorter than the inner tepals are spirally arranged inside the upper part of the floral cup. The tepals also are spirally arranged outside the andræcium. As in *Pereskia*, they also show a very gradual transition from the outer calyciform to the inner petaliform tepals and form a perianth. After fertilization (if this at all occurs) the upper part of the flower bearing the perianth, andræcium and the style drops off leaving a conical depression on the top of the fruit.

The unilocular inferior ovary is deeply sunken in the floral cup. The placentation is parietal, the number of placentæ being equal to the number of stigmatic lobes which are superposed on placental radii, i.e., the stigma is commissural. Each placenta is bilobed and bears two, rarely more rows of circinotropous type of ovules. As in *Pereskia*, the carpels are spirally arranged.

Vascular Anatomy of the Flower.—The lower part of the receptacle contains a much dissected siphonostele of numerous conjoint vascular bundles which freely anastomose with one another. In its basal region the receptacle is elliptical to circular in outline but becomes variously ridged upward. As the receptacular bundles ascend they divide repeatedly and diverge out to occupy a more peripheral position. Some of the receptacular bundles are more conspicuous than the others (Figs. 25-35). After ascending almost to the top of the receptacle, and giving out the vascular supply to the perianth and the andræcium, the remaining stelar bundles turn inward and descend down the receptacle round the ovary, obviously with inverse orientation. To start with, these recurrent bundles are numerous (Figs. 29-35) but as they descend down the placenta, their number is reduced to two for each placenta (Figs. 27-29). Still lower down, the two bundles in a placenta also unite to form a single inversely oriented vascular bundle supplying ovular traces (Figs. 24 and 26). A transverse section of the ovary of *Opuntia* somewhere in the middle region (Fig. 26), therefore, exhibits only two rings of vascular bundles—the outer ring of normally oriented receptacular bundles and the middle ring of inversely oriented recurrent bundles. The innermost third ring of normally oriented bundles, seen in *Pereskia* is thus apparently completely suppressed here. Further down, the six recurrent bundles divide to form a network of veins in the base of the locule.

The recurrent bundles as they are passing down supply six amphivasal bundles for the style (Figs. 24, 31-33). It is significant to note that these bundles occur on the same radii as the placenta down below—

a fact which throws some light on the morphological nature of these bundles. Inside the style these bundles traverse straight upward and terminate in the stigmatic lobes. It follows, therefore, that the stigma in *Opuntia* is commissural.

The bracteoles receive their vascular supply from the outer ring of receptacular bundles. Most commonly two vascular strands enter each bracteole and divide one or more times inside the bracteole.

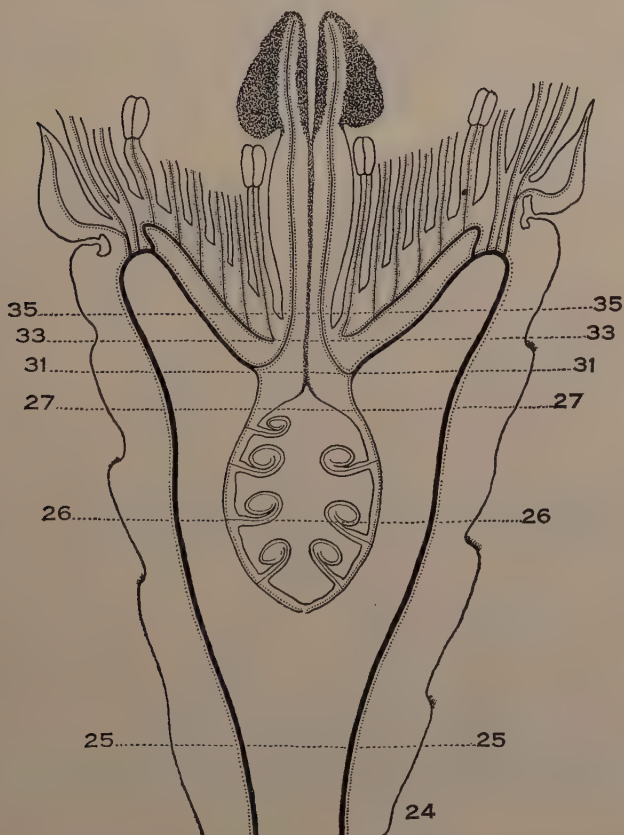


FIG. 24. *Opuntia dillenii*.—Diagrammatic representation of the longitudinal section of a flower showing the origin of the recurrent ring and vascular supply of different organs, $\times 4$.

The Perianth.—The vascular supply of the tepals is given off by the receptacular bundles in the region of their down turning. As in *Pereskia*, a few outer tepals receive one trace each which divides immediately into three while the rest of them receive several vascular bundles each. Inside each tepal the vascular bundles undergo repeated divisions to form a network of veins so that in a transverse section, there is an arc of numerous collateral bundles in each tepal.

Numerous mucilage ducts, often separating two vascular bundles from each other, are present in each tepal.

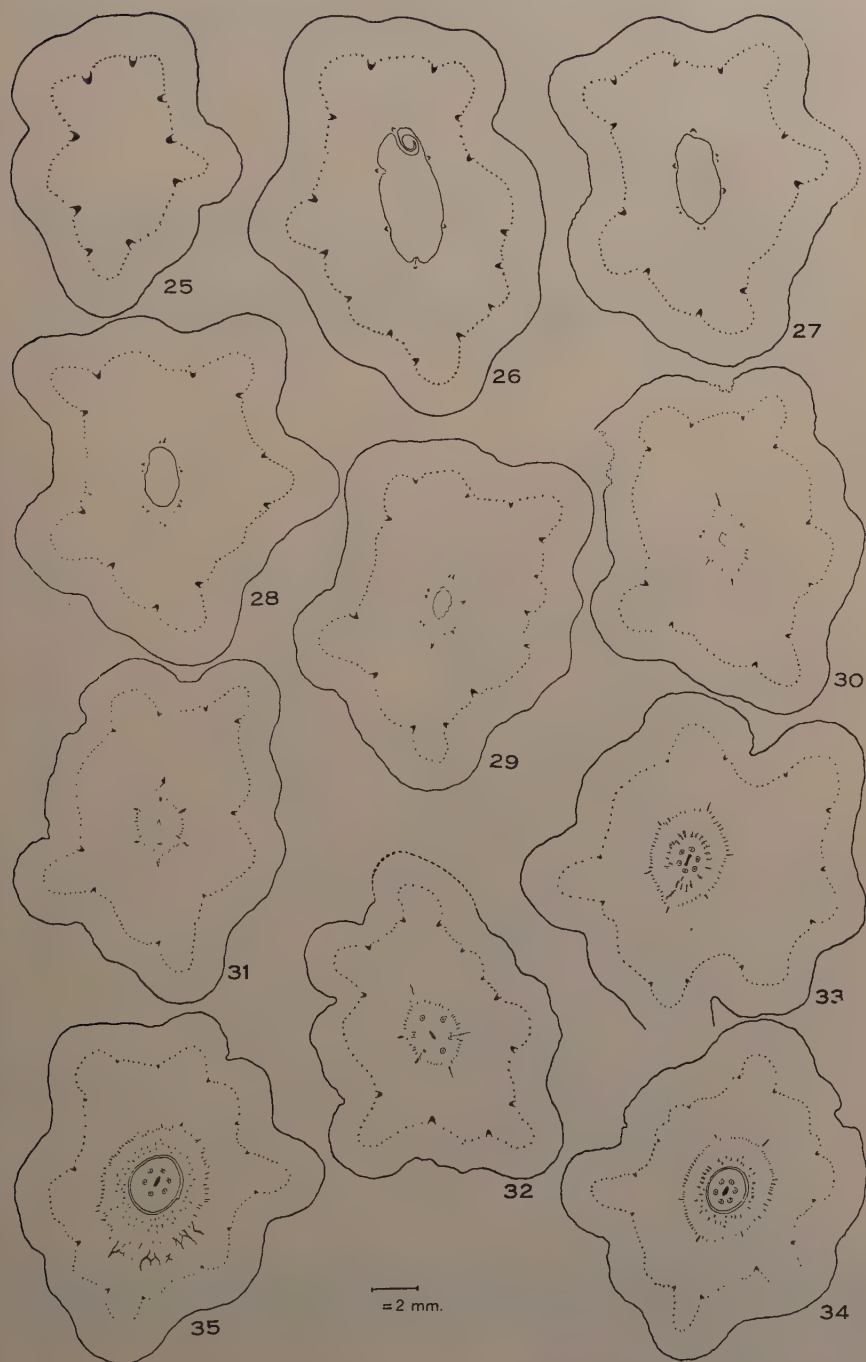
The Andræcium.—The vasculature of the andræcium in *Opuntia dillenii* is essentially similar to that in *Pereskia bleo*. Several amphivasal vascular strands—the stamen fascicle traces are given off from the receptacular bundles after the latter have supplied the perianth. Each stamen fascicle trace after traversing upward for a while diverges inward and downward in the direction of the base of the style and divides to give off traces to several stamens as it does in *Pereskia* (Figs. 24, 33–35). The single staminal bundle which is also amphivasal remains unbranched throughout its course and terminates in the anther.

Mammillaria tenuis DC.

External Morphology of the Flower.—The bell-shaped, yellowish white flowers are borne in the axils of the tubercles round the top and on the sides of the stem. Numerous hairs surround the base of each flower. The receptacle of the flower is cylindrical and glabrous and is continuous indistinguishably into the perianth above. There is a cupular depression on the top of the receptacle, from the bottom of which arises the stout, columnar style crowned with four stigmatic lobes. There are about 25 tepals all united at the base. The numerous stamens are spirally arranged in the upper portion of the floral cup around the style. The ovary, as usual, is inferior and unilocular. The placentation is parietal and each of the four bilobed placentæ bears two rows of circinotropous type of ovules (Fig. 40). The carpels are spirally arranged. This is indicated by the successive appearance of loculi and placentæ in the base of the ovary (Figs. 37–40) and of the two sets of vascular bundles which supply the style (Figs. 43–46).

Vascular Anatomy of the Flower.—The lower part of the receptacle contains a siphonostele of about 12 conjoint vascular bundles which are neither essentially equidistant from one another nor are equal in size (Fig. 37). In their upward course these bundles diverge out to take a more peripheral position (Figs. 38–42). After reaching the upper level of the locule, the receptacular bundles give off the vascular supply of the perianth and andræcium and then turn inward to descend down almost to the base of the locule and behave exactly as they do in *Opuntia* except that they do not branch (Figs. 36, 41–42).

The vascular supply of the style in this species is somewhat interesting. The recurrent bundles as they are passing down separate off two sets of four bundles each. The four bundles occurring on placental radii are larger in size, have double roots and traverse the whole length of the style and terminate in the stigmatic lobes. The stigma in this species is thus commissural. The other four bundles occupy positions which should ordinarily be occupied by carpellary dorsals, i.e., they lie on radii which alternate with placental radii (Figs. 43–46). They are small and generally disappear blindly in the base of the style (Figs. 43–50) and do not continue further into it except very rarely. It will be recalled that these latter bundles are not represented in *Opuntia*.



FIGS. 25-35. *Opuntia dillenii*.—Serial transverse sections of a flower bud from base upward. Figs. 31-32 show the stylar bundles diverging inward from the recurrent bundles. Figs. 33-35 show the appearance of staminal traces; in the last figure the bundles of the middle recurrent ring approaching the bundles of the outer ring on the lower side.

Mammillaria tenuis, therefore, offers good evidence for the interpretation of the stigma in the family.

The Perianth.—The tepals receive their vascular supply from the receptacular bundles just at the level of their bending down (Fig. 36). The single vascular strand of a tepal immediately divides into three bundles (Figs. 51, 52), by the further divisions of which an arc of numerous collateral bundles, occurring nearer to the adaxial surface of the tepal is formed (Figs. 52, 53). Numerous mucilage cavities, frequently separating one vascular bundle from another, are present in each tepal.

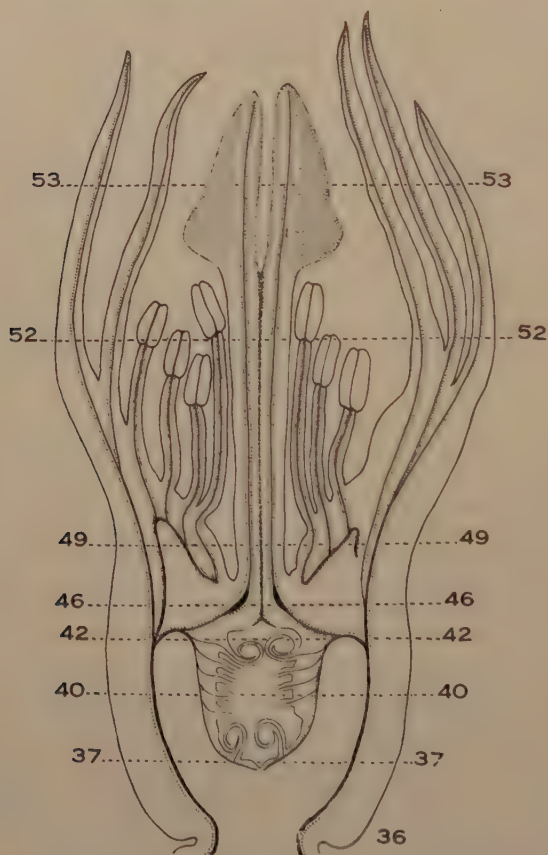
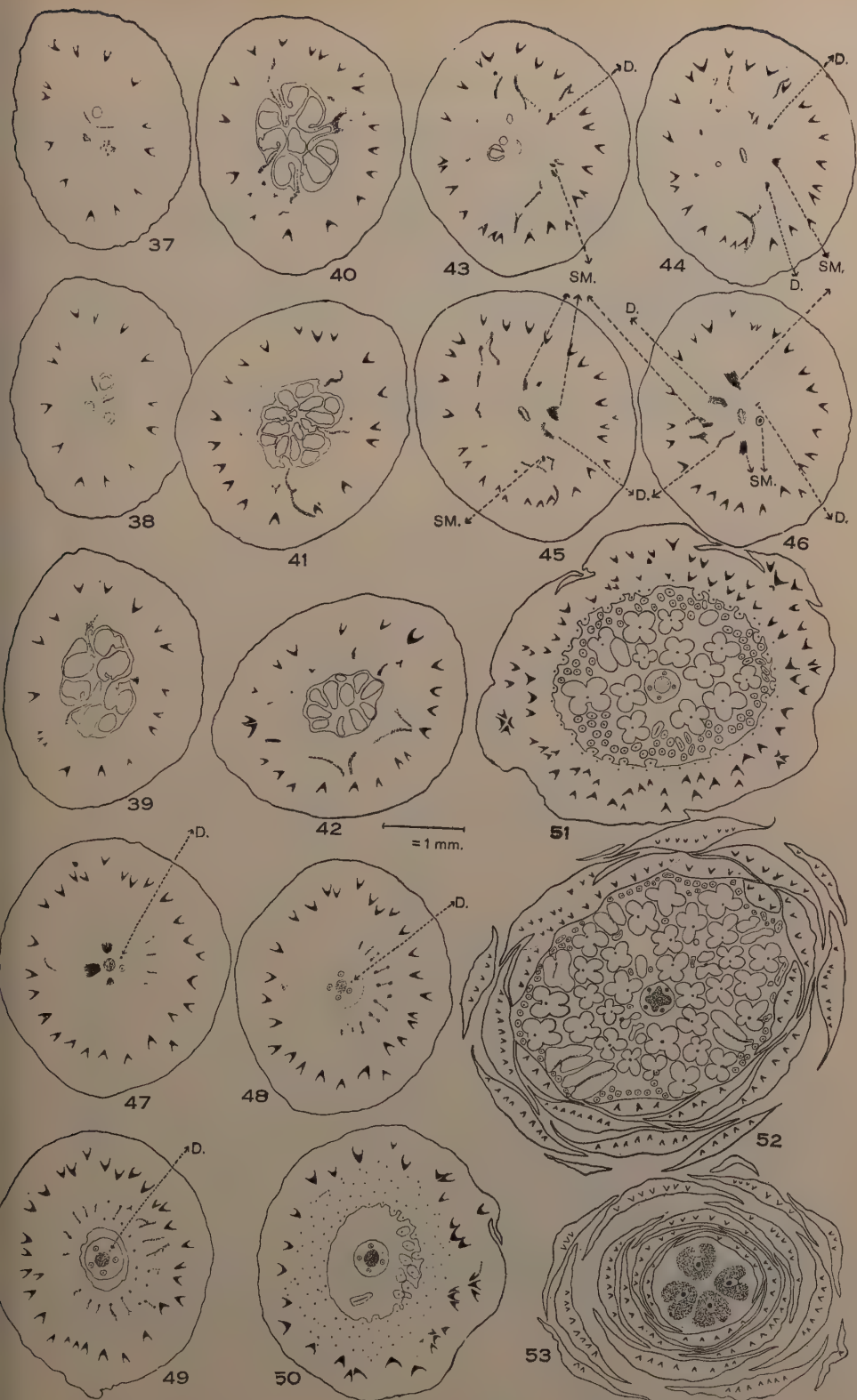


FIG. 36. *Mammillaria tenuis*.—Diagrammatic representation of the longitudinal section of a flower showing the origin of recurrent ring and vascular supply to different organs, $\times 12$.



FIGS. 37-53. *Mammillaria tenuis*.—Serial transverse sections of a flower bud from base upward. Figs. 37-40 show the successive appearance of the locules and the four placentæ. Figs. 41-42 show the recurrent bundles approaching the bundles of the outer ring. Figs. 43-44 show the origin of first carpellary dorsal (D.) and the first secondary marginal (SM.). Fig. 45 shows the appearance of the second and third secondary marginals and the second carpellary dorsal. Fig. 46 shows the appearance of the fourth secondary marginal and the third and fourth carpellary dorsals; the first carpellary dorsal has entirely disappeared and the second persists as a weak strand. Fig. 47 shows the complete disappearance of the first, third and fourth carpellary dorsals, the second carpellary dorsal still persisting as a weak strand; several stamen traces have also appeared on the right side. Figs. 48-52 show the separation of the stamens, style, tepals. Fig. 53 shows the four stigmatic lobes.

The vasculature of the andræcium is essentially similar to that in *Pereskia* and *Opuntia* (Figs. 36, 47-52).

Rhipsalis cassutha Gärt.

External Morphology of the Flower.—The flowers are sessile, solitary and borne along the joints of the plant. They are small, about one-third of an inch long. The cylindrical, prominently swollen receptacle is green and bears a bracteole (Fig. 56). The perianth consists of about ten tepals. The outer 4 or 5 tepals are small, tough and broad with acute apices (calyciform) while the remaining ones are large, membranous, oblong in shape and with obtuse apices (petaliform). They form a perianth. There are about 20 stamens spirally arranged on the edge of the floral cup inner to the perianth. Between the style and the bases of the stamens, there is a prominent thick disc (Fig. 54). The stout, columnar style arises from the centre of a cupular depression on the top of the receptacle, overtops the andræcium and is crowned with 3-4 swollen stigmatic lobes. The ovary is inferior and is sunken, rather deep in the receptacle. It is incompletely three-chambered by three vertical partitions, each bearing two rows of ovules, giving the impression that the two ovules on a placenta arise by the branching of a common funicle in a transverse section of the ovary (Fig. 56). Developmental studies reveal that these incomplete partitions result from the growth *en masse* of the primordia of the two rows of ovules on a placenta for some time. Thus these partitions represent the fusion products of the basal parts of the funicles of the two rows of ovules on a placenta both in the lateral and vertical directions. Such a conclusion is also supported by vascular anatomy of the flower, since two vascular strands enter the common funicle at its base, remain united up to the point of separation of the two funicles, where they again separate to supply a single bundle to each of the ovules (Fig. 56). Such a condition in *Rhipsalis cassutha* is somewhat similar to that of *Opuntia dillenii* (Tiagi, 1954), where sometimes two ovular primordia arising side by side grow *en masse* for sometimes giving the impression that the two ovules arise by the branching of a single funicle and also to that of *Cereus tortuosus* where Guignard (1886) reports that the main trunk of the funicle gives rise to about thirty branches or 'secondary funicles' each tipped by an ovule. Further in another species of *Rhipsalis*, *R. houlettiana*, the rather long funicles of the two rows of ovules on a

placenta are entirely free from one another, nay, even there is a little space between the two rows of ovules on a placenta.

The carpels are spirally arranged. This is indicated by the successive appearance of placenta, locules in the basal region of the ovary (Figs. 55–56) and of the vascular bundles which supply the style (Figs. 57–60).

Vascular Anatomy of the Flower.—The lower part of the receptacle contains a ring of approximately 13 conjoint vascular bundles. As these bundles ascend up in the receptacle, they may show some divisions and anastomosis. After supplying traces for the perianth and the andræcium, the receptacular bundles bend inward and downward as recurrent bundles which descend down the receptacle around the ovary with inverse orientation (Figs. 54–56) and behave exactly as they do in *Mammillaria*.

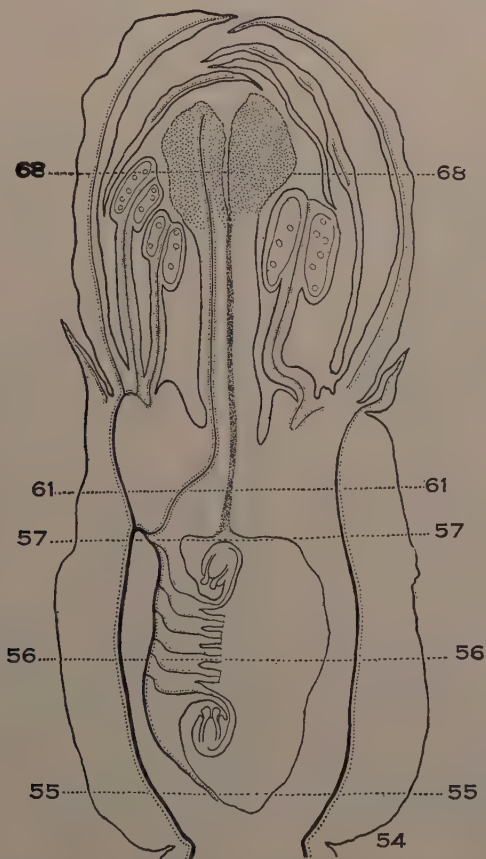


FIG. 54. *Rhipsalis cassutha*.—Diagrammatic representation of the longitudinal section of a flower bud showing the origin of recurrent ring and vascular supply to different organs, $\times 23$.



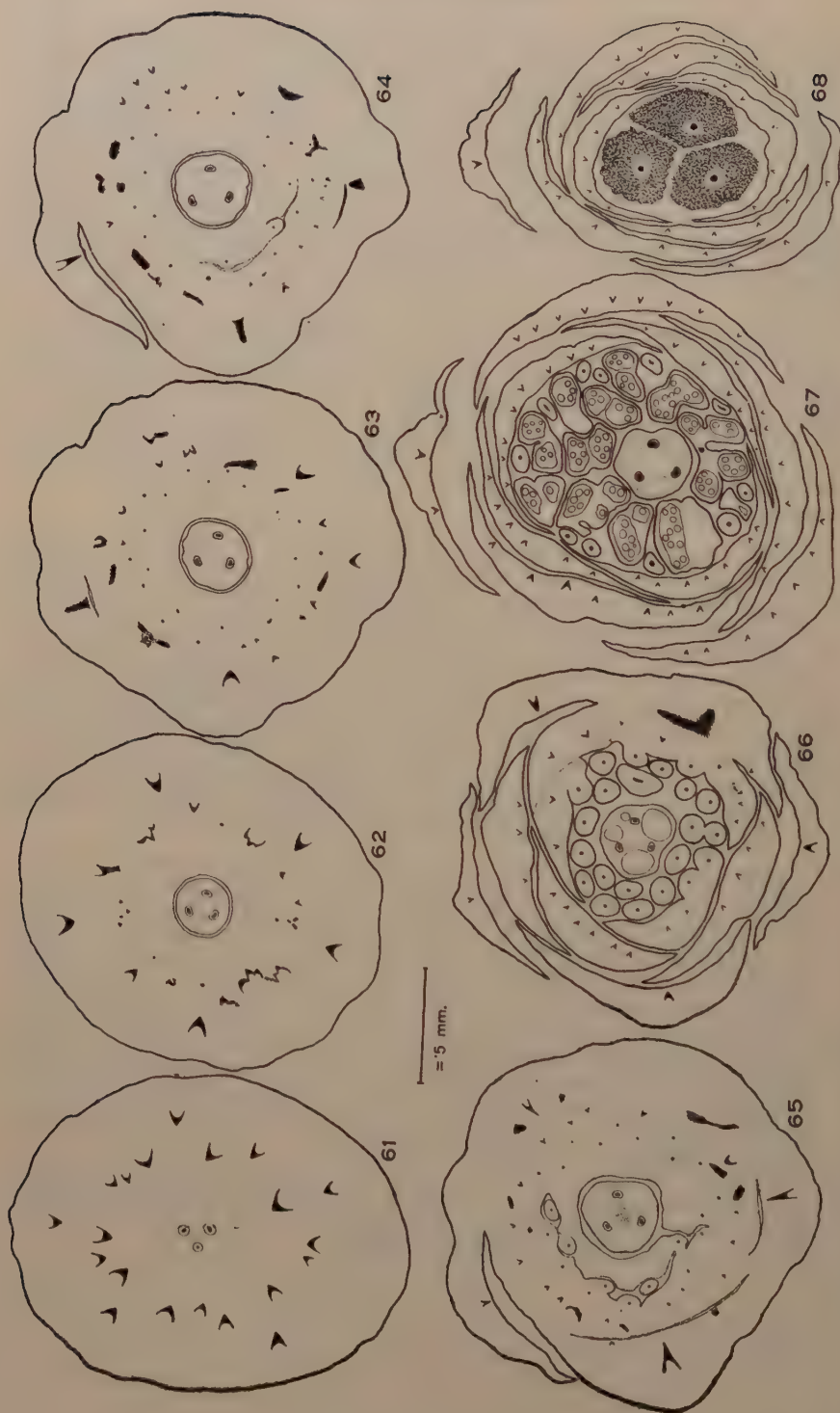
FIGS. 55-60. *Rhipsalis cassutha*.—Serial transverse sections of a flower bud from base upward. Fig. 55 shows the successive appearance of the three locules and placenta. Fig. 56. On the right lower side, a bracteole with a single vascular strand is separating; the five vascular bundles diverging out from the outer ring are destined to supply the first five tepals. Fig. 57. The placenta are disappearing; three interplacental outgrowths (L.) are becoming conspicuous. Two pairs of secondary marginals (SM.) on the radii of placenta (P.) and two carpellary dorsals (D.) alternating with them have also appeared. Fig. 58. The three interplacental outgrowths have met in the centre and the ovary has become three-chambered; one of the carpellary dorsal has disappeared. Fig. 59. The third secondary marginal has appeared; one of the three locules has disappeared. Fig. 60. The three secondary marginal bundles are prominent while the carpellary dorsals and the locules have completely disappeared.

As the upper region of the ovary is reached, the placenta disappear successively and three prominent lamellae alternating with the placenta begin to protrude inward from the inner surface of the locule (Fig. 57, L.). Ultimately, these interplacental lamellae meet in the centre, making the ovary trilobular in its upper region (Fig. 58). According to Buxbaum (1953), these interplacental lamellae represent the fused margins of the adjoining carpels, while the placenta are borne on the midribs of the carpels.

The vascular supply of the style in this species is essentially similar to that of *Mammillaria tenuis*. Three strong bundles with double roots on the radii of placenta and three weak bundles on radii, alternating with placental radii separate off successively from the recurrent bundles as they are passing down (Figs. 57-60). The former traverse the whole length of the style and terminate in the stigmatic lobes (Figs. 54, 61-68), while the latter bundles which occupy positions that should ordinarily be occupied by carpellary dorsals, disappear blindly after traversing a little distance in the interplacental lamellae (Figs. 57-60). It follows, therefore, that the stigma in *Rhipsalis* like *Opuntia* and *Mammillaria* is also commissural. The vascular bundles in the style are separated by prominent mucilage cavities (Figs. 66-67).

The Perianth and the Androecium.—The vascular supply of the tepals is derived from the receptacular bundles just before their down turning (Fig. 54). Quite early five vascular bundles diverge out from the receptacular stele and successively enter the first five tepals (Figs. 54, 61-66). The vascular traces of the remaining tepals are adnate with stamen fascicle traces (Figs. 54, 61-66). The single vascular strand entering a tepal divides immediately into three bundles and by further divisions of these bundles an arc of numerous collateral bundles is formed in each tepal (Figs. 66-68). Each stamen fascicle trace after its separation divides to furnish a single amphivasal bundle to each of the few stamens on the same and adjacent radii; the staminal bundle remains unbranched throughout its course.

Rhipsalis houlettiana Lemaire is essentially similar to *Rhipsalis cassutha* but the receptacle is star-shaped in transverse section with five furrows alternating with five ridges.



FIGS. 61-68. *Rhipsalis cassutha* continued.—Fig. 61. The outer five bundles are destined to supply the first five tepals; the rest of the bundles are 'compound' and meant to supply the remaining tepals and the stamens. Figs. 62-67 show the departure of the five outer bundles into the first five tepals and divisions in the remaining vascular bundles to furnish traces to the inner tepals and the stamens. Fig. 68 shows the three stigmatic lobes.

DISCUSSION

Vascular Ground Plan of the Cactus Flower.—A comparative study of the vascular anatomy of the flower of *Pereskia bleo*, *Opuntia dillenii*, *Mammillaria tenuis* and *Rhipsalis cassutha*, species representing all the three tribes of the Cactaceæ confirms the generally held belief that *Pereskia* is the most primitive genus of the family Cactaceæ. The vascular ground plan of *Pereskia* can, perhaps, be regarded as nearest to the original condition in the family. Here, the recurrent bundles after supplying ovular traces give off branches for the third and innermost ring of normally oriented vascular bundles. In all probability, these innermost bundles are the carpellary bundles (marginals and secondary marginals) which remain adnate to the recurrent bundles in the lower region. The recurrent bundles in the placental regions are, therefore, not simple stelar bundles but compound which have incorporated within them, so to say, the innermost carpellary bundles. This explains satisfactorily their behaviour of giving out ovular traces in their lower region.

The condition in *Opuntia*, *Mammillaria* and *Rhipsalis* is further complicated by the complete non-separation of the carpellary bundles of the innermost third ring from the middle ring of recurrent bundles. Thus the third innermost ring of vascular tissue in these species is completely "lacking".

The Style and the Stigma.—It will be recalled that in *Pereskia* the vascular supply of the style is furnished by six bundles which arise from the recurrent bundles in the upper region. These bundles are given out on radii alternating with those of the placenta. This is an important structural feature which leads me to conclude that these bundles are none other than the carpellary dorsals. If this is so, then the style in *Pereskia* receives only the carpellary dorsals and since everyone of them supplies a stigma, the latter has to be interpreted as carinal.

In other species studied, the condition, however, is different. Both in *Mammillaria* and *Rhipsalis*, there are two sets of vascular bundles for the style—those arising on placental radii traverse the whole length of the style and enter the stigmatic lobes. These stelar bundles have double roots and each one of them on account of its position should in my opinion be interpreted as fusion product of adjacent secondary marginal bundles belonging to the adjoining carpels. The bundles of the other set lie on radii alternating with those of the placenta—they occupy positions which should ordinarily be occupied by carpellary dorsals and in all probability, should be interpreted as such. It will be recalled that these bundles end blindly in the base of the style and do not continue further except very rarely (Figs. 44-50). *Opuntia dillenii* is essentially similar to *Mammillaria tenuis* and *Rhipsalis cassutha*

except that the carpellary dorsals are entirely unrepresented. As a logical consequence of this interpretation of the styler bundles it follows that the stigma in these species has to be interpreted as commissural.

The Andræcium.—The vasculature of the andræcium in the Cactaceæ is somewhat interesting. Several vascular strands are given off from the stelar bundles in the region of their down turning and each such strand divides to supply a single amphivasal bundle to each of the several stamens on the same and adjacent radii. Each such strand is thus a stamen fascicle trace (Wilson, 1937). A stamen fascicle trace is defined as "a strong bundle arising from the receptacular stele, either independently or fused with the vascular supply of sepals or petals which by divisions forms the vascular supply of a number of stamens". Wilson (1937) reports the presence of such stamen fascicle traces in several species of the families Dilleniaceæ, Crossosomataceæ, Ochnaceæ, Cochlospermaceæ, Bixaceæ, Guttiferæ, Flacourtiaceæ, Bombacaceæ and Malvaceæ and has used this feature to support the telomic interpretation of the angiospermic stamen.

The Inferior Ovary.—Vascular anatomy of the flower of the Cactaceæ furnishes convincing proof of the stem nature of the outer region of the ovary 'wall' and lends strong support to the view that the inferior ovary has resulted by the invagination of the tip of the receptacle followed by fusion of the ovary with the receptacular cup. This is borne out by the fact that the stelar bundles after furnishing traces to the peripheral organs (perianth and andræcium) bend inward and downward as inversely oriented recurrent bundles. As Sharma (1949) has also interpreted, these recurrent bundles in all probability are stelar bundles. Therefore, the outer region of the ovary 'wall' appears to be receptacular in nature at least up to the point of bending down of the stelar bundles. However, vascular anatomy of the flower cannot decide as to the nature of the part of the receptacle beyond the point of down turning of the stelar bundles (Puri, 1951, 1952). In *Rhipsalis cassutha* this part is sufficiently developed. Similar down turnings in the course of the stelar bundles of the receptacle have been reported in certain species of the Rosaceæ (Jackson, 1934; MacDaniel, 1940), Santalaceæ (Smith and Smith, 1942 a, 1942 b) and Calycanthaceæ (Smith, 1928).

Puri (1951, 1952) who has discussed in detail the nature of the inferior ovary *vis a vis* its vascular supply also admits that in those cases where inversely oriented recurrent bundles occur, vascular anatomy of the flower does help us in interpreting the outer region of the ovary 'wall' as receptacular. The stem nature of the outer region of the 'wall' of inferior ovary in the Cactaceæ is also confirmed by the fact that the bracteoles on the receptacle very commonly in *Pereskia* and occasionally in *Opuntia* bear flowers in their axils. In *Opuntia fulgida* (Johnson, 1918) both the unripe ovary and the ripe fruit may give rise to flowers and another crop of fruits. Four or five generations of fruits may thus be formed on a single plant during one season. I have myself noted this behaviour quite commonly for *Pereskia bleo* and occasionally for *Opuntia dillenii* and *Opuntia elatior*.

Placentation.—There can be little doubt that placentation in Cactaceæ is parietal although Buxbaum (1953) calls it “median laminar”, “displaced to a pseudoparietal position”. According to Buxbaum (1953) “there is no true difference between the position of placentæ in *Mesembryanthemum* in which displacement occurs during development and the Cactaceæ in which displacement appears to be of a primary nature”. Buxbaum’s interpretation of placentation in the Cactaceæ explains the presence of commissural stigmas in *Opuntia*, *Mammillaria* and *Rhipsalis* and is also interesting in connection with the origin of Cactaceæ from Aizoaceæ via *Mesembryanthemum* because the ontogenetic turning over of the locules of *Mesembryanthemum* has now become of a “primary nature” in the Cactaceæ. Such a view, however, does not take into consideration the facts revealed by a comparative study of the vascular anatomy of the flower of *Pereskia*, *Opuntia*, *Mammillaria* and *Rhipsalis*—genera representing all the three tribes of the Cactaceæ. In *Pereskia*, the stigma is carinal, the vascular supply of the style being formed by carpellary dorsals. In *Opuntia*, *Mammillaria*, and *Rhipsalis*, however, the stigmas are commissural and the vascular supply of the style is furnished by secondary marginal bundles.

One more point which deserves attention here is the nature of the septæ that often divide the locule into separate chambers in the upper region. According to Buxbaum (1953), these septæ represent the fused margins of the adjacent carpels while the placentæ are borne on the midribs of the carpels. It may be recalled that in *Pereskia* these septæ arise on placental radii and are not homologous with those of *Rhipsalis* and *Mammillaria* where they alternate with the placental radii.

SUMMARY

1. Vascular anatomy of the flower of *Pereskia bleo*, *Opuntia dillenii*, *Mammillaria tenuis*, and *Rhipsalis cassutha* has been studied; it confirms the generally held belief that *Pereskia* is the most primitive genus in the Cactaceæ.

2. In every case the receptacular bundles after reaching its top turn inward and descend down with inverse orientation. In *Pereskia*, the carpellary bundles which arise from the recurrent bundles and constitute the third innermost ring of normally oriented bundles are interpreted to be adnate with the recurrent bundles only in their basal regions but in *Opuntia*, *Mammillaria* and *Rhipsalis*, the carpellary bundles are believed to be entirely incorporated within the recurrent bundles as a result of which the innermost third ring of normally oriented carpellary bundles is apparently “lacking”.

3. In *Pereskia*, the vascular supply of the style is formed by what are interpreted as carpellary dorsals and the stigma is carinal: in *Opuntia*, *Mammillaria* and *Rhipsalis*, the vascular supply of the style is formed by what are interpreted as secondary marginal bundles and the stigma thus become commissural here. In *Mammillaria* and *Rhipsalis*, stubs of what are interpreted as carpellary dorsals persist in the base of the style but these are entirely unrepresented in *Opuntia*.

4. All the floral leaves, including the carpels, are spirally arranged and this is amply borne out by the vascular anatomy of the flower: there is one trace for each tepal in *Mammillaria* and *Rhipsalis* but in *Pereskia* and *Opuntia* the inner tepals receive several vascular bundles each.

5. The vascular supply of the andrœcium is constituted by several stamen fascicle traces, each of which divides to supply several stamens on the same and adjacent radii.

6. Vascular anatomy of the flower of the Cactaceæ furnishes convincing proof of the stem nature of the outer region of the 'wall' of the inferior ovary.

7. The placentation is parietal.

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FRESH-WATER EUGLENINEÆ FROM HYDERABAD, INDIA—I

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THE first contribution, perhaps, to our knowledge of the fresh-water Euglenineæ from India comes from G. H. Grant, whose description of some of the genera of algæ, collected from Calcutta, appeared in Cantor's paper "On the general features of Chusan, etc.," in 1842. Among the algæ described in this communication, mention is made of *Euglena longicauda*, which was, in most probability, an organism belonging to *Phacus longicauda* group.

In 1855, H. J. Carter described organisms "resembling *Astasia*" from material containing species of *Chara* and *Nitella* collected from fresh-water ponds near Bombay. There is every possibility that the organisms observed were some species of *Urceolus*, as according to him they were "Infusoria with a transparent flask-shaped sac terminated by a long cilium". Later (1856 *a*), from the same locality, he recorded the occurrence of parasites in *Euglena viridis* and *Lepocinclis* spp. (*Crumenula* spp., p. 116, pl. 9, figs. 11-14) and in the same year (1856 *b*) mention was made by him of the presence of *Lepocinclis texta* (Duj.) Lemmermann emend. Conrad (*Crumenula texta* Duj., p. 119, pl. 6, figs. 53, 56, 60 and 60 *a*) and also of *Astasia* sp., *Peranema trichophorum* Ehr. (*Astasia limpida* Duj., pl. 6, figs. 45-48), *Euglena spirogyra* Ehr., *E. acus* Ehr., *E. viridis* Ehr. and *E. deses* Ehr. along with the *Phacus pleuronectes* (O.F.M.) Duj. (pl. 7, fig. 88). The figure given for *Phacus pleuronectes* could also be that of the *Ph. brachykentron* Pochmann, but in the absence of any description of the species, especially of the nature and position of the paramylum, nothing can be said definitely regarding its real nature. Again in 1858, he reported the occurrence of a species of *Trachelomonas* along with *Euglena viridis* in fresh-water pools in the vicinity of Bombay, but doubts can be expressed about the identity of this organism with that of the *Trachelomonas*, as it passed into a 16-celled stage during division. The next year (1859) he recorded two species of *Lepocinclis*, *L. ovum* (Ehr.) Lemm. (*Euglena zonalis*, p. 17, pl. 1, fig. 16) and *L. fusiformis* (H. J. Carter) Lemm. emend. Conrad (*Euglena fusiformis*, p. 17, pl. 1, figs. 15, 17) from a tank near Bombay and in 1869 he described a new species of *Euglena* (*E. tuba*?, p. 249, pl. 17, figs. 10-12) with a globular transparent cyst having a trumpet-shaped opening and a single cilium. The identity of this species will remain obscure due to the inadequate description given by the author (Gojdics, 1953, p. 190).

Hansgirg, in 1902, recorded *Euglena agilis* Carter (*E. pisiformis* Klebs, p. 14) from a lake near Igatpuri. In 1908 Kashyap gave an

account of a species of *Euglena*, which occurred in large numbers in a tank at Shalimar Gardens, Lahore. According to him the organism somewhat resembled *E. tuba* Carter, but the real nature of it will remain uncertain due to the incomplete description given by the author. Bhatia (1930) described a few species belonging to the genera *Euglena* Ehr., *Phacus* Duj., *Lepocinclis* Perty, *Trachelomonas* Ehr., *Peranema* Stein and *Urceolus* Meresch. from Kashmir. In 1936 Banerji reported the occurrence of *Euglena viridis* Ehr. in the plankton in Lower Bengal and, in the next year (1937), Skvortzov published an account of species belonging to the genera *Euglena* Ehr., *Phacus* Duj., *Lepocinclis* Perty and *Trachelomonas* Ehr. from fresh-water habitats from Burma. Gonzalves and Joshi (1943 *a, b*) recorded *Euglena proxima* Ehr. from rain-water pools and puddles in the vicinity of Bombay and afterwards in 1946, in course of their investigations on the ecology of fresh-water algæ, reported a few species. Very recently Skuja, in 1949, has contributed a very valuable paper on the Burmese Algæ, wherein he has described 47 members of Euglenineæ.

It is worth mentioning here that from 2 pickled samples collected by Prof. Khanna of the Biology Department, Rangoon University, a careful worker like Skvortzov, could describe 58 species of Euglenineæ, out of which 23 were new to science. This shows how rich the fresh-water flora can be in a tropical country.

Unfortunately this class of algæ has not received adequate attention in the past from Indian systematists.

The author intends to take up a systematic survey of the fresh-water Euglenineæ of India, and this paper, it is hoped, will be the first of the series.

The author expresses his gratitude to Prof. M. Sayeeduddin, Head of the Botany Department, Osmania University, for providing him laboratory facilities and for his encouragement, to the Rev. Father H. Santapau, Chief Botanist to the Government of India, for kindly translating the diagnosis of the new species into Latin.

DESCRIPTION OF THE SPECIES

EUGLENINEÆ

Euglenaceæ

Genus *Euglena* Ehrenberg

1. *E. limnophyla* Lemmermann

(Text-Fig. 1)

Pascher and Lemmermann, 1913, p. 130, fig. 205; Walton, 1915, p. 371, pl. 14, fig. 9; Skuja, 1948, p. 194; Skuja, 1949, p. 163; Gojdics, 1953, p. 103, pl. 11, fig. 6.

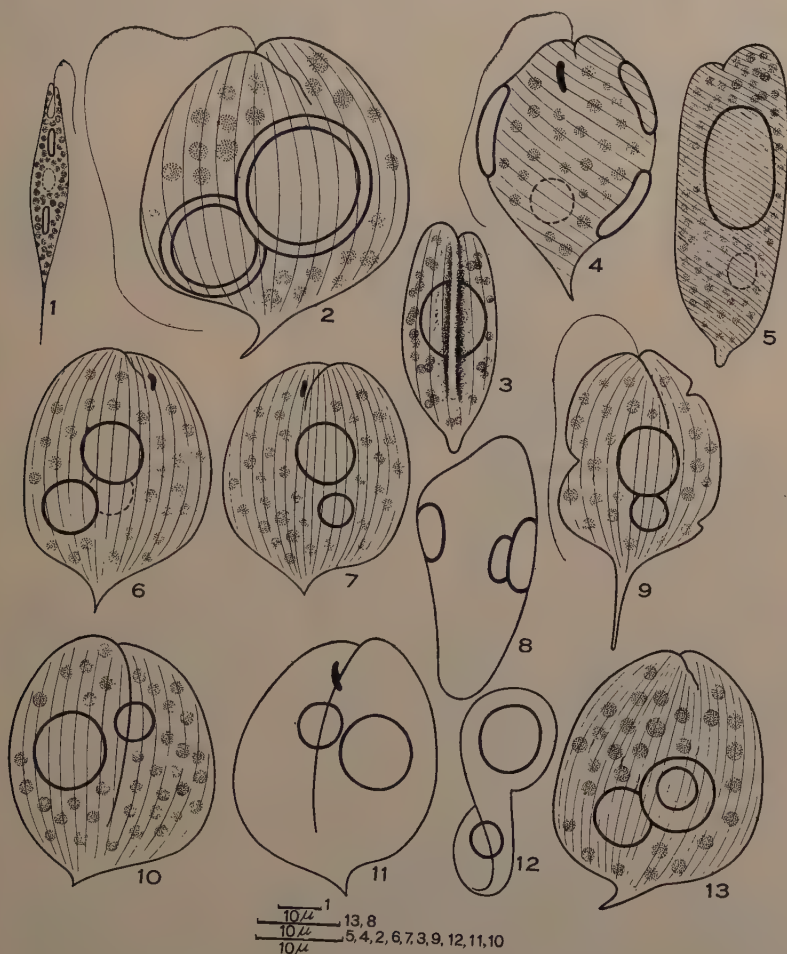
Body slightly metabolic, fusiform with a straight needle-like tail. Pellicle with very faint spiral striations. Flagellum short and thick. Stigma large. Chromatophores disc-shaped and many. Pyrenoids

absent. Paramylum 2 elongate rods, anterior and posterior to the nucleus.

Length 60–80 μ ; breadth 7–10 μ .

On the basis of size the Hyderabad forms seem to be intermediate between the type species and var. *minor* Drezepolski.

Habitat.—Pocharum lake; planktonic.



TEXT-FIGS. 1–13. Fig. 1. *Euglena limnophyla* Lemmermann. Fig. 2. *Phacus acuminatus* Stokes var. *Janei* var. nov. Fig. 3. *Phacus caudatus* Hübner. Fig. 4. *Phacus enigmaticus* Drez. Fig. 5. *Phacus cylindrus* Pochmann. Figs. 6–7. *Phacus brachykentron* Pochmann. Fig. 8. *Phacus Heimi* Lefevre var. *minor* var. nov. Fig. 9. *Phacus indicus* Skvortzov. Figs. 10–12. *Phacus curvicauda* Swirenko. Fig. 13. *Phacus Heimi* Lefevre var. *minor* var. nov.

2. *E. oxyuris* Schmarda

(Text-Fig. 15)

Pascher and Lemmermann, 1913, p. 130, fig. 207; Walton, 1915, p. 369, pl. 14, fig. 4; Bhatia, 1930, p. 362; Skvortzov, 1937, p. 70, pl. 9, fig. 3; Gonzalves and Joshi, 1946, p. 175, pl. 6, fig. 2; Skuja, 1948, p. 197; Skuja, 1949, p. 163.

Body elongate, cylindrical, twisted and produced into a pointed colourless tail. Pellicle spirally striated. Flagellum about one-third as long as the body. Chromatophores disc-shaped, small and many. Paramylum 2 large elongated links, one anterior and the other posterior to the nucleus. Pyrenoids absent.

Length 160–200 μ ; breadth 12–18 μ .

This is a very variable species. Out of the many varieties described in the literature, Gojdics (1953, p. 120–22) has retained only two varieties, var. *charkowiensis* (Swirenko) Chu and var. *minima* Bourrelly. On the basis of size almost all species so far described from India, including the present one, can well be placed under the former variety.

Habit.—Standing waters.

3. *E. tripteris* (Duj.) Klebs.

(Text-Fig. 14)

Pascher and Lemmermann, 1913, p. 130, fig. 201; Walton, 1915, p. 371, pl. 14, fig. 7; Skuja, 1948, p. 198, pl. 23, figs. 12–13; Skuja, 1949, p. 163; Gojdics, 1953, p. 122, pl. 18, fig. 3 *a–d*.

Phacus tripteris Duj., Pochmann, 1942, p. 215, fig. 129.

Body slightly metabolic, elongately ribbon-shaped, spirally twisted, with a long and acute tail. Pellicle longitudinally striate; striae very fine and faint. Flagellum more or less half the length of the body. Chromatophores many, disc-shaped. Paramylum 2, elongate rod-like, one anterior and the other posterior to the nucleus.

Length 100–210 μ ; breadth 15–23 μ .

Habit.—Pakhal lake. A very rare species.

4. *E. spirogyra* Ehr.

(Text-Fig. 25)

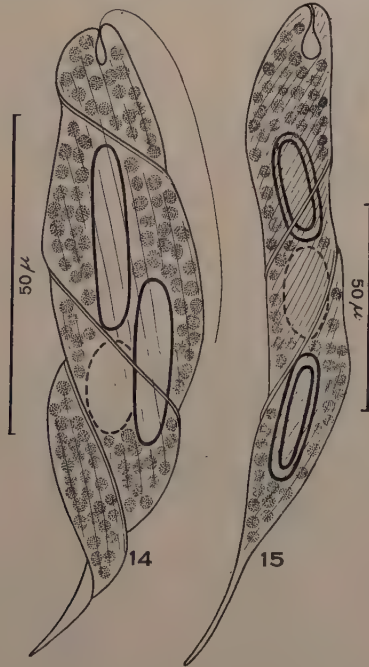
Pascher and Lemmermann, 1913, p. 131, fig. 208; Fritsch and Stephens, 1921, p. 69, fig. 29 A; Bhatia, 1930, p. 362; Skvortzov, 1937, p. 70, pl. 9, fig. 4; Skuja, 1949, p. 163; Gojdics, 1953, p. 111, pl. 14, fig. 2 *a–b*.

Body long cylindrical, weakly metabolic, slightly narrowed towards the anterior end while posteriorly produced into an acute slightly bent tail, which is distinctly set off from the rest of the body. Pellicle yellowish brown, in rare cases reddish brown, with spiral rows of

knob-like prominences. There is an alternation of rows having large knob-like prominences with those having smaller ones. Chromatophores green, disc-shaped and many. Pyrenoids absent. Paramylum 2 elongate annular rings, the one anterior and the other posterior to the nucleus. Flagellum very short, less than one-third of the length of the body.

Length 100–110 μ ; breadth 13–14 μ .

Habit.—In standing waters; rarely planktonic.



TEXT-FIGS. 14–15. Fig. 14. *Euglena tripteris* (Duj.) Klebs. Fig. 15. *Euglena oxyuris* Schmarida.

Genus *Lepocinclis* Perty

5. *L. ovum* (Ehr.) Lemmermann var. *punctato-striata*

Lemmermann *forma*

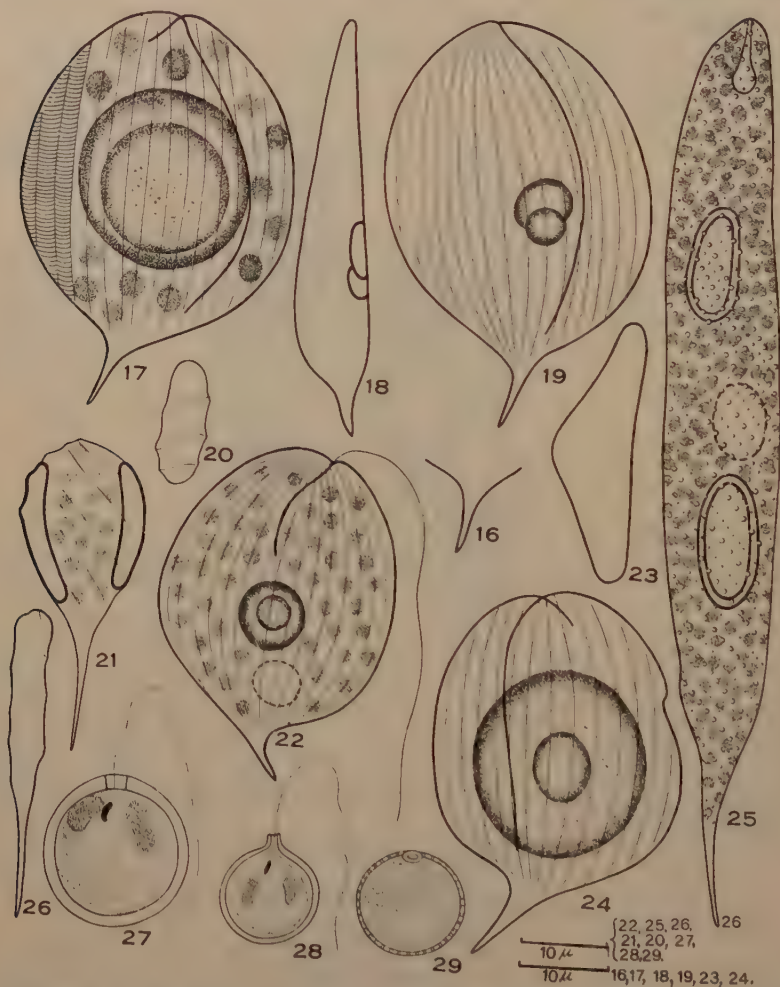
(Text-Fig. 40)

Pascher and Lemmermann, 1913, p. 134, fig. 217; Conrad, 1935, p. 45, fig. 37; Skvortzov, 1937, p. 71, pl. 9, fig. 5.

Body ovoid, broadly rounded towards both the ends. Posterior end with an acute point. Pellicle yellowish brown, spirally striated. Punctæ faint. Chromatophores disc-shaped, many. Paramylum 2 large elliptic rings.

Length $30.5\ \mu$; breadth $24.5\ \mu$.

The Hyderabad specimen somewhat differs from the variety described by Skvortzov (*op. cit.*). His organisms were more or less elliptic and were narrower. It also differs from the type in having a short knob-like anterior end in place of a short cylindrical collar.



TEXT-FIGS. 16-29. Figs. 16-19. *Phacus orbicularis* Hübner. Figs. 20-21. *Phacus pseudonordstedti* Pochmann. Fig. 22. *Phacus pleuronectes* (O.F.M.) Duj. Figs. 23-24. *Phacus pseudonordstedti* Pochmann. Fig. 25. *Euglena spirogyra* Ehr. Fig. 26. *Phacus chelomonas volvocina* Ehr. var. *derephora* Conrad. Fig. 27. *Trachelomonas volvocina* Ehr. Fig. 28. *Trachelomonas perforata* Awerinzew emend. Deflandre.

6. *L. indica* Skvortzov

(Text-Figs. 41-42)

Skvortzov, 1937, p. 71, pl. 9, figs. 6-8.

Body ovoid, triangular. Anterior end broadly rounded. Posterior end abruptly broad and produced into an acuminate short process. Pellicle firm, yellowish and spirally striated. Chromatophores disc-shaped, small and many. Paramylum 2, large ring-shaped bands.

Length 23-24.5 μ ; breadth 18-20.5 μ .

Habit.—A very rare species. Only a few specimens were observed in a collection from Pakhal lake.

Genus *Phacus* Duj.

7. *Ph. pusillus* Lemmermann

(Text-Figs. 30-33)

Pascher and Lemmermann, 1913, p. 141, fig. 223; Walton, 1915, p. 384, pl. 17, fig. 16; Pochmann, 1942, p. 124, fig. 7 a-d.

Body elliptic ovoid; margins entire, straight or slightly convex in the middle. Anterior end broad and rounded; posterior end with a slightly pointed tip. Two wing-like thickenings one on either side of the body. Pellicle spirally striated. Stigma rod-shaped. Flagellum $\frac{1}{2}$ the length of the body. Paramylum 2; one at the anterior end and lateral, the other at the posterior end and more or less on the long axis.

Length 18-19 μ ; breadth 8-9 μ .

Habit.—In stagnant pools; Amberpet.

8. *Ph. Skujai* Skvortzov

(Text-Figs. 34-36)

Pochmann, 1942, p. 128, fig. 14; Skuja, 1948, p. 199.

Body asymmetrical, sigmoid in outline; margins more or less folded on each other. Anterior end broad; posterior end narrowed into a short and slightly curved tail. Paramylum 3, one ring-shaped and the other two cylindrical, or all cylindrical. Pellicle striated, striae slightly right over left. Stigma broad.

Length 12-13.5 μ ; breadth 4.5-6.5 μ .

In the degree of torsion the Hyderabad flagellate comes very near *Ph. inflexus* (Kisselew) Pochmann (*op. cit.*, p. 133, fig. 20), but differs from it in its smaller size and in the shape of paramylum.

Habit.—Rain-water pools; Kewdaban.

9. *Ph. cylindrus* Pochmann

(Text-Fig. 5)

Pochmann, 1942, p. 131, fig. 17; *Ph. oscillans* Fritsch and Stephens, 1921, p. 71, fig. 29 E.

Body cylindrical with parallel margins, more or less three times as long as broad and slightly asymmetrical. Anterior end as broad as the middle portion, with two unequal broadly rounded lip-like projections. Posterior end very slightly tapering and with a short blunt tail, which is not placed on the long axis of the cell. Pellicle striated left over right. Paramylum 1, large and oval with broad rounded ends.

Length 30–38 μ ; breadth 10–13.5 μ .

Habit.—In a puddle near Adikmet.

Reported from South Africa. The Hyderabad form is slightly larger than the type.

10. *Ph. ænigmaticus* Drez.

(Text-Fig. 4)

Pochmann, 1942, p. 136, figs. 22–25; Skuja, 1948, p. 199.

Body pear-shaped, asymmetrical, with spirally left over right striated pellicle. The posterior end narrowed into a short, slightly bent and sharp tail. The longitudinal fold reaching the middle portion of the cell. Paramylum 3, lateral and mussel-shaped; usually the two at the upper end, the third towards the lower end of the body. Flagellum as long as the body.

Length 26–29.5 μ ; breadth 18–20.5 μ .

Habit.—Common in standing waters.

The specimens observed were slightly broader than the type.

11. *Ph. acuminatus* Stokes var. *Janei* var. nov.

(Text-Fig. 2)

Body ovoid, very broad and twisted; triangular in the top view. Anterior end slightly narrowed. Posterior end broad and abruptly produced into a short, bent and pointed tail. Pellicle longitudinally striated. Paramylum 2, of unequal diameter (14–17 μ and 11–12 μ), ring-shaped, lying close to each other. Chromatophores many and disc-shaped. Flagellum twice as long as the body.

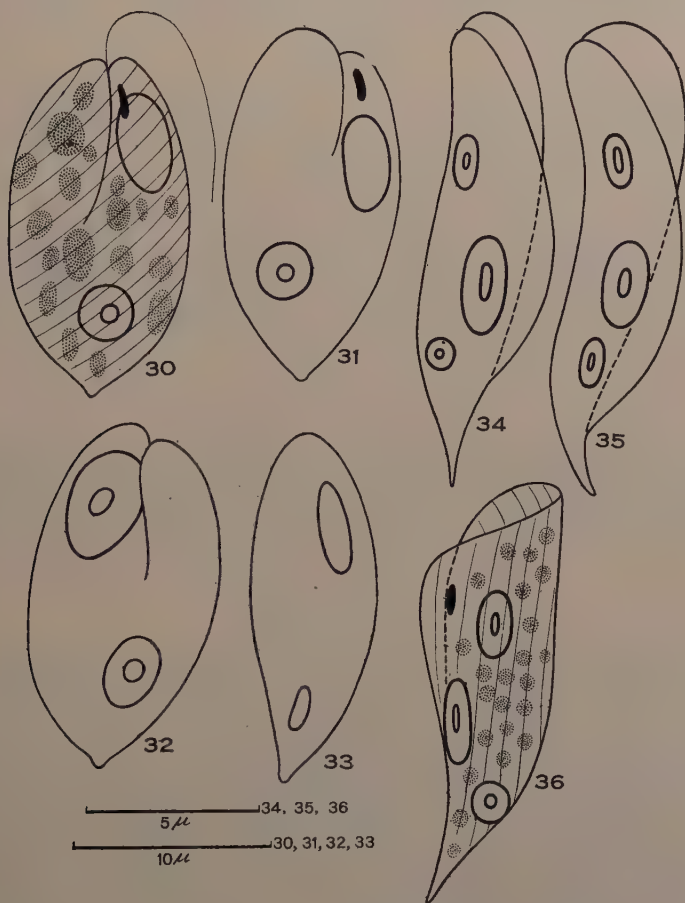
Length 35–36.5 μ ; breadth 29–32 μ .

Habit.—Planktonic, Pakhal lake.

This variety seems to occupy an intermediate position between *Ph. acuminatus* subsp. *acuticauda* (Roll) Pochmann (1942, p. 143, fig. 32 n) and *Ph. acuminatus* subsp. *megapyrenoidea* (Roll) Pochmann

(*op. cit.*, p. 144, fig. 32 o), both of which have been described from Russia. It resembles the former in the possession of two unequal paramylum bodies lying close to each other, but differs from it in the shape of the posterior end and in the size of the cell. In the shape and size of the body, it comes very close to the latter, but has two paramylum bodies instead of one.

I have named this variety after my renowned teacher Professor F. W. Jane.



TEXT-FIGS. 30-36. Figs. 30-33. *Phacus pusillus* Lemmermann. Figs. 34-36. *Phacus Skujai* Skvortzov.

12. *Ph. brachykentron* Pochmann
(Text-Figs. 6-7)

Pochmann, 1942, p. 145, fig. 33.

Body ovoid and more or less asymmetrical in outline. Anterior end slightly attenuated. Posterior end broad, abruptly passing

into a weakly differentiated short and pointed tail, which is more or less straight. Dorsal fold reaching the centre of the body. Pellicle longitudinally striated, but converging at both the ends. Flagellum shorter than the length of the body. Stigma fairly large. Paramylum 2 of unequal diameter, lying close together.

Length 26–30 μ ; breadth 20–22 μ .

Habit.—Collected from a pond, Mahboobnagar.

13. *Ph. caudatus* Hübner

(Text-Fig. 3)

Pascher and Lemmermann, 1913, p. 138, fig. 237; Walton, 1915, p. 381, pl. 17, fig. 3; Pochmann, 1942, p. 146, fig. 35 *a-z*; Allegre and Jahn, 1943, p. 235, figs. 7–9; Skuja, 1948, p. 199.

Body very slightly asymmetrical and ovoid. Anterior end broad; posterior end more or less attenuate, ending in a short blunt tail. Pellicle longitudinally striated. The longitudinal fold prominent, reaching the lower half of the body. Paramylum large, ring-shaped and placed on the long axis of the cell. Flagellum as long as the body.

Length 25–29 μ ; breadth 11–25.5 μ .

Habit.—Very common in puddles and rain-water pools.

It is worth mentioning here that, out of the many specimens examined by the author, only a few were in possession of the second smaller paramylum, which is so characteristic of this species. The specimens also differ from the type in having a short blunt tail and in smaller dimensions.

14. *Ph. indicus* Skvortzov

(Text-Fig. 9)

Skvortzov 1937, p. 76, pl. 10, fig. 9; Pochmann, 1942, p. 154, fig. 45.

Body ovoid, asymmetrical in outline, slightly twisted and narrowed at both the ends. Posterior end produced into a straight and pointed tail, which is about one-third as long as the body.

Lateral margins with 1–2 sharp notches. Pellicle longitudinally striated. Paramylum 2, disc-shaped, unequal in diameter and lying close together. Chromatophores many and disc-shaped. Flagellum as long as the body.

Length 36–37 μ ; breadth 17–20 μ .

Habit.—Very rare species. Collected only once from the Pakhal lake.

Reported from Poland, S. China and Rangoon (Burma). The Hyderabad forms differ from the type in the possession of two unequal paramylum bodies.

15. *Ph. curvicauda* Swirencu

(Text-Figs. 10–12)

Pochmann, 1942, p. 155, figs. 49–51; Skuja, 1949, p. 163.

Body broadly ovoid, more or less as long as broad. Anterior end slightly narrowed; posterior end broad and slightly concave towards the tail. The margins thick, cushion-like and in cross-section S-shaped. The tail short, slightly bent and very sharp. Pellicle longitudinally striated. Paramylum 2, disc-shaped and unequal in size, lying side by side.

Length 25–30.5 μ ; breadth 22–25.5 μ .

Habit.—In ponds. Adikmet.

16. *Ph. Heimi* Lefevre var. *minor*. var. nov.

(Text-Figs. 8, 13)

Body fairly thick and more or less lobed in cross-section. Anterior end slightly tapering; posterior end with a short bent tail. Longitudinal fold quite prominent. Paramylum 3, two lying over the other in the middle of the cell and the other situated over the lobe. Flagellum as long as the body. Pellicle longitudinally striated.

Length 27–31 μ ; breadth 24–25 μ .

Habit.—In small pools below the Meeralam tank bund.

The type species which was first described by Lefèvre from the Botanic Garden, Saigon, has larger dimensions and more prominently striated pellicle. The present variety is much smaller in size and the striæ are extremely faint and fine.

17. *Ph. orbicularis* Hübner

(Text-Figs. 16–19, 23–24)

Pascher and Lemmermann, 1913, p. 138, fig. 256; Walton, 1915, p. 380, pl. 16, fig. 8; Pochmann, 1942, p. 178, figs. 78–79; Gonzalves and Joshi, 1946, p. 175, pl. 5, fig. 13.

Body ovoid; in optical cross-section more or less three-lobed with the obtuse dorsal lobe gradually sloping towards the margins. In the side-view (in the optical longitudinal section) the dorsal side convex and the ventral flat or slightly convex. Posterior end either broad (fig. 24) or narrowed (fig. 19), ending in a short, bent and sharp tail. Paramylum 2, disc-shaped; one larger than the other, one lying on the other or close together. Pellicle longitudinally striated.

Length 35–46.5 μ ; breadth 28–31.5 μ .

The Hyderabad specimens are smaller than the type. The species is very variable in shape of the body and in the size and position of the paramylum.

Habit.—Common in standing waters.

18. *Ph. pleuronectes* (O.F.M.) Duj.

(Text-Fig 22)

Pascher and Lemmermann, 1913, p. 138, fig. 236; Walton, 1915, p. 380, pl. 16, fig. 9; Fritsch and Stephens, 1921, p. 71; Bhatia, 1930, p. 361; Pochmann, 1942, p. 180, figs. 82-84; Allegre and Jahn, 1943, p. 236, figs. 22-23; Skuja, 1948, p. 199; Skuja, 1949, p. 164.

Body asymmetrical in outline, one side more convex than the other. Pellicle longitudinally striated. Dorsal fold reaching upto the centre of the body. The posterior end abruptly passing in a short, bent and pointed tail. Paramylum 2, of unequal size and disc-shaped; one lying on the other.

Length 31-37.5 μ ; breadth 20-26.5 μ .

The form is quite smaller than the type and in this respect it comes close to *Ph. minutus* Playfair, but differs from it in the shape of the posterior end and the tail. It may be an intermediate form between these two species.

Habit.—Quite common in standing waters.

19. *Ph. onyx* Pochmann

(Text-Figs. 51-52, 56)

Pochmann, 1942, p. 192, fig. 98.

Body ovoid and asymmetric in outline. Anterior end markedly narrowed. Posterior end very broad and abruptly produced into a short, bent or more or less hooked tail. One of the lateral margins with 2 notches. Pellicle longitudinally striated. Paramylum 2 of unequal diameter (figs. 51-52) or only one (fig. 56).

Length 32-36 μ ; breadth 23-26.5 μ .

Habit.—Not recorded.

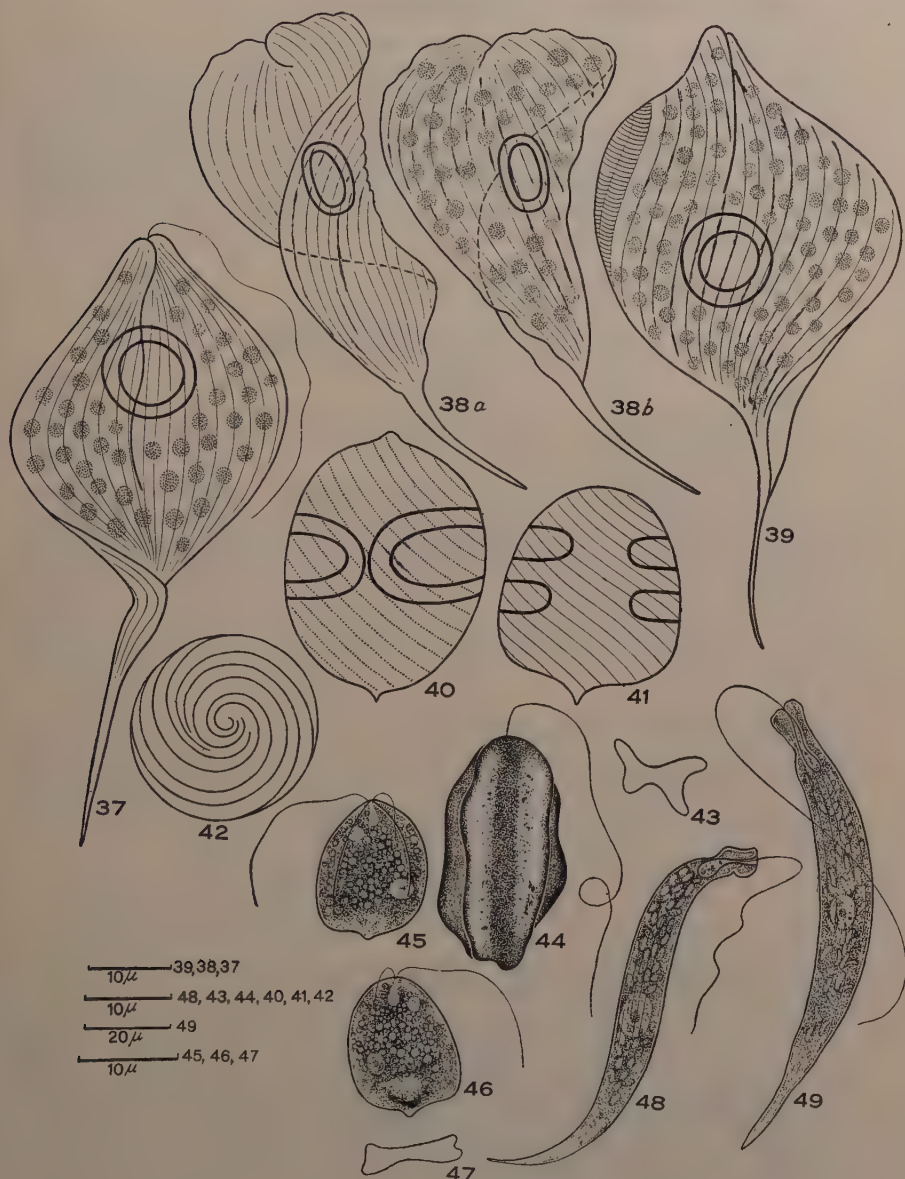
Reported from Europe and Sunda Islands.

20. *Ph. meson* Pochmann

(Text-Fig. 50)

Pochmann, 1942, p. 195, fig. 103 a-c; *Ph. longicauda* var. *brevicaudata* Skv., 1922, p. 193, fig. 6; *Ph. longicauda* var. *indica* Skv., 1937, p. 73, pl. 9, fig. 15, pl. 10, fig. 1.

Body broadly ovoid. Anterior end rounded, slightly narrower than the body diameter. Margins entire. Pellicle longitudinally striated, with fine transverse striæ. Posterior end narrowed into a tail, which is less than $\frac{1}{2}$ the length of the body. Paramylum ring-shaped, 2 in number, situated more or less on the long axis; one in the middle, the other towards the posterior end. Chromatophores disc-shaped.



TEXT-FIGS. 37-49. Fig. 37. *Phacus tortus* (Lemmermann) Skvortzov. Fig. 38 a-b. *Phacus ephippion* Pochmann. Fig. 39. *Phacus circumflexus* Pochmann. Fig. 40. *Lepocinclis ovum* (Ehr.) Lemmermann var. *punctato-striata* Lemmermann. Figs. 41-42. *Lepocinclis indica* Skvortzov. Figs. 43-44. *Petalomonas alata* Stokes. Figs. 45-47. *Notosolenus Skujai* spec. nov. Fig. 48. *Menoidium tortuosum* Stokes. Fig. 49. *Menoidium falcatum* Zach.

Length including the tail 100–102 μ ; breadth 49–50 μ .

The alga seems to agree with *Ph. longicauda* var. *brevicaudata* Skv. (89–90 $\mu \times 40 \mu$) in the possession of entire margins, but differs from it in being larger in size. In their relative shape also the Hyderabad specimens are broader than the Chinese forms. It also agrees with *Ph. longicauda* var. *indica* Skv. described from Rangoon, in the possession of two large paramylum bodies, but differs from it in the absence of marginal incisions and also being much broader than the Rangoon specimens.

Habit.—Planktonic; Uppal tank.

21. *Ph. circumflexus* Pochmann

(Text-Fig. 39)

Pochmann, 1942, p. 206, fig. 119 a–f; *Ph. torta* (Lemm.) Skvortzov, 1937, p. 72, pl. 9, fig. 13.

Body asymmetrical, more or less broadly ovoid and twisted. Anterior end tapering into a lip-like projection. Posterior end produced into a pointed and slightly curved tail. Pellicle spirally striated. The longitudinal fold prominent. Paramylum central and ring-shaped.

This species can easily be differentiated from *Ph. tortus* (Lemm.) Skv. by its asymmetrical body and by the unequal curvature of the margins of the latter.

Length 73–75 μ ; breadth 34–35.5 μ .

Habit.—Rain-water pools.

Reported also from Europe and Uzbekistan.

22. *Ph. ephippion* Pochmann

(Text-Figs. 38 a–b)

Pochmann, 1942, p. 208, fig. 120 a–d; *Ph. longicauda* var. *torta* Lemm., Fritsch and Rich, 1929, p. 76, figs. B–F on p. 77.

Body ovoid, broadly rounded at the anterior end. Margins folded along the axis of the body and give it a saddle-like appearance. Posterior end produced into a short, curved and pointed tail, which is less than $\frac{1}{2}$ the length of the body. Paramylum 1, ring-shaped and central.

Length 61–63.5 μ ; breadth 30–32 μ .

Habit.—Rain-water pools.

The Hyderabad forms differ from the type in the possession of a ring-shaped paramylum.

Reported from S. Africa.

23. *Ph. tortus* (Lemm.) Skvortzov

(Text-Fig. 37)

Pochmann, 1942, p. 209, figs. 121 *a-d* and 122 *a-e*.

Body symmetrical, slightly twisted; broadest in the middle and then tapering towards both the ends. Anterior end in some cases more attenuate than the posterior end. Posterior end produced into a long, straight or slightly curved tail. Paramylum 1, ring-shaped, more or less on the long axis of the cell. Chromatophores numerous and disc-shaped.

Length 73–79 μ ; breadth 34–38 μ .

Habit.—A very common species in permanent and semi-permanent ponds.

The species varies much in its torsibility, but in almost all cases the body does not take more than one turn.

Reported from Europe, Russia, China and Sunda Islands.

Skuja (1949, p. 164) describes a form from Rangoon under *Ph. longicauda* (Ehr.) Duj. var. *torta* Lemm.

24. *Ph. pseudonordstedti* Pochmann

(Text-Figs. 20–21, 26)

Pochmann, 1942, p. 219, figs. 134–35.

Body ovoid in outline; top and side-views both cylindrical. Pellicle spirally striated, with 6–7 spirals originating from the left side. The posterior end narrowed into a long straight and pointed tail. Paramylum 2, laterally placed watch-glass-shaped bodies.

Length 21–24 μ ; breadth 14–15 μ . Tail 12–13 μ long.

Habit. In rain-water pools. Rare.

Reported from Europe.

Genus *Trachelomonas* Ehrenberg

25. *Tr. volvocina* Ehr.

(Text-Fig. 27)

Pascher and Lemmermann, 1913, p. 145, fig. 246; Walton, 1915, p. 389, pl. 18, fig. 2; Fritsch and Stephens, 1921, p. 72; Deflandre, 1928, p. 55, figs. 1–6; Skvortzov, 1937, p. 76, pl. 10, fig. 10; Fritsch and Rich, 1937, p. 221; Gonzalves and Joshi, 1943, p. 121; Skuja, 1948, p. 199; Skuja, 1949, p. 165.

Lorica spherical. Flagellum-opening with an annular thickening. Membrane smooth, brown or yellowish brown. Chromatophores 2. Flagellum two or three times as long as the lorica.

Diameter of the lorica $17-17.5\mu$; diameter of the flagellum-opening $1.5-2.0\mu$.

Habit.—Rain-water pools; common.

26. *Tr. volvocina* Ehr. var. *derephora* Conrad

(Text-Fig. 28)

Deflandre, 1928, p. 55, figs. 7-9; Skvortzov, 1937, p. 76, pl. 10, fig. 11.

Lorica spherical, with distinct short tube-like collar. Membrane smooth and brown. Chromatophores 2. Flagellum longer than the lorica.

Diameter of the lorica $10-11.5\mu$; diameter of the collar 1.5μ .

Habit.—With the former species; a very rare alga.

Reported from Europe, Java and Burma.

27. *Tr. verrucosa* Stokes

(Text-Fig. 57)

Pascher and Lemmermann, 1913, p. 146, fig. 253; Walton, 1915, p. 390, pl. 18, fig. 5; Deflandre, 1928, p. 61, figs. 78-79; Skuja, 1948, p. 200.

Lorica spherical, densely covered with warts. Flagellum-opening without any thickening or annular rim. Membrane reddish brown.

Diameter of the lorica $23-24\mu$; diameter of the flagellum-opening $1.7-2.3\mu$.

Habit.—Rain-water pools.

Reported from North and South America.

28. *Tr. perforata* Awerinzew emend. Deflandre

(Text-Fig. 29)

Deflandre, 1928, p. 62, figs. 73-74.

Lorica spherical, uniformly perforate. The perforations quite separate and of equal diameter. Flagellum-opening annular, without any prominent collar. Membrane yellowish brown to light brown.

Diameter of the lorica $12-12.5\mu$; diameter of the flagellum-opening $1.1-1.5\mu$.

Habit.—Common in fresh-water ponds.

Reported from Europe and America.

29. *Tr. intermedia* Dangeard

(Text-Figs. 58-59)

Pascher and Lemmermann, 1913, p. 146, fig. 257; Walton, 1915, p. 390, pl. 18, fig. 4; Deflandre, 1928, p. 71, figs. 146-47, 157-58;

Skvortzov, 1937, p. 78, pl. 10, fig. 17; Skuja, 1948, p. 200; Skuja, 1949, p. 164.

Lorica subspherical or broadly ellipsoidal; finely punctate. Membrane brown. Flagellum-opening with annular thickening. Flagellum twice as long as the lorica. Chromatophores many.

Length 20–21 μ ; breadth 17–17.5 μ ; diameter of the flagellum-opening 1.1–1.8 μ .

Habit.—Common in fresh-water ponds and lakes.

Reported from Europe, U.S.A., S. America, Manchuria and Burma (Rangoon).

30. *Tr. bacillifera* Playfair var. *minima* Playfair

(Text-Fig. 54)

Deflandre, 1928, p. 82, figs. 244 and 254.

Lorica subspherical or weakly ellipsoidal, thickly covered with spinous outgrowths. Spines obtuse and rod-like. Membrane deep red. Flagellum-opening circular, without collar.

Length 23–24 μ ; breadth 18–19.5 μ .

Habit.—Rain-water pools.

Reported from Australia and France.

Astasiaceæ

Genus *Astasia* Duj.

31. *A. lagenula* (Schew) Lemmermann

(Text-Fig. 55)

Pascher and Lemmermann, 1913, p. 157, fig. 315; Walton, 1915, p. 403, pl. 22, fig. 2.

Body elongate, lageniform, tapering towards the anterior end from a very broad and rounded posterior end, which gives it a pear-shaped appearance. Pellicle smooth. Flagellum as long as the body. Paramylum spherical; nucleus median.

Length 25–35 μ ; breadth 10–12 μ .

Habit.—Rain-water pool; Amberpet.

Reported from Bali Islands (Malay Archipelago) and U.S.A.

32. *A. Klebsii* Lemmermann

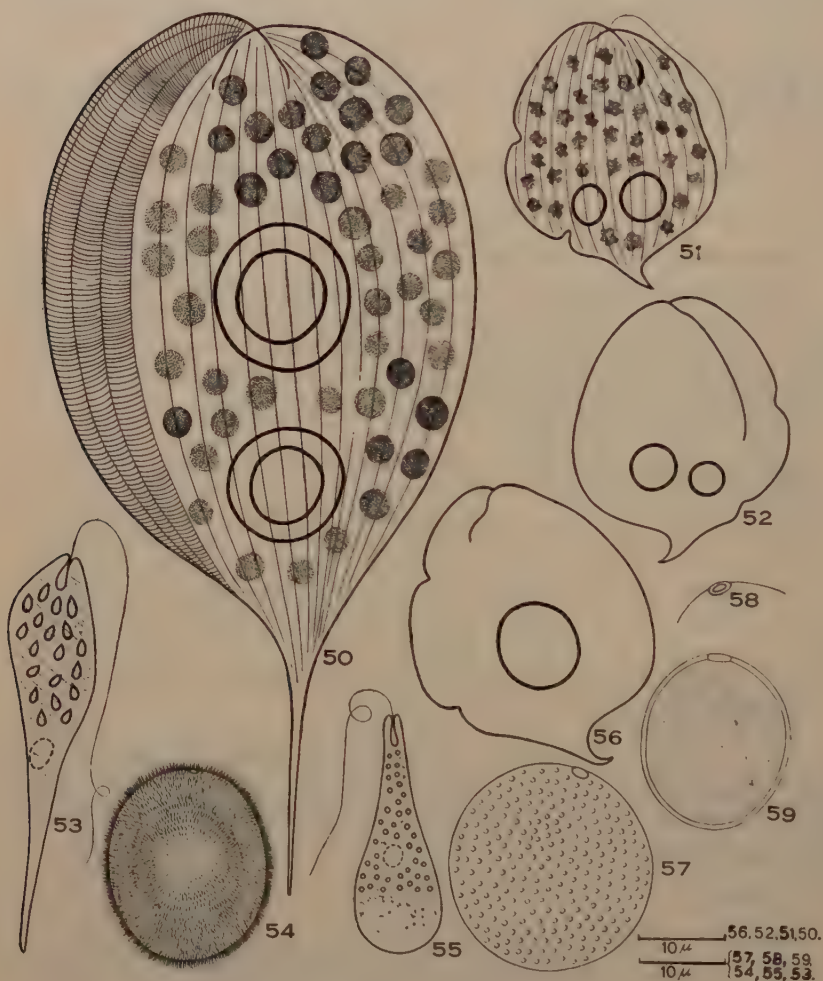
(Text-Fig. 53)

Pascher and Lemmermann, 1913, p. 159, fig. 316; Walton, 1915, p. 403, pl. 22, fig. 5.

Body fusiform, posteriorly drawn out into a long tail-like process. Pellicle spirally striated; striae very faint and often indistinct. Paramylum oval; nucleus median. Flagellum as long as the body.

Length 45–60 μ ; breadth 10–20 μ .

Habit.—Stagnant ditches.



TEXT-FIGS. 50–59. Fig. 50. *Phacus meson* Pochmann. Figs. 51–52. *Phacus onyx* Pochmann. Fig. 53. *Astasia Klebsii* Lemmermann. Fig. 54. *Trachelomonas bacillifera* Playfair var. *minima* Playfair. Fig. 55. *Astasia lagenula* (Schew) Lemmermann. Fig. 56. *Phacus onyx* Pochmann. Fig. 57. *Trachelomonas verrucosa* Stokes. Figs. 58–59. *Trachelomonas intermedia* Dangeard.

Genus *Menoidium* Perty

33. *M. falcatum* Zach.

(Text-Fig. 49)

Pascher and Lemmermann, 1913, p. 160, fig. 327; Walton, 1915, p. 405, pl. 22, fig. 10.

Body very narrow sickle-shaped; posterior end pointed. Pellicle fairly firm; nucleus median. Flagellum as long as the body. Paramylum elongate bodies.

Length 110–120 μ ; breadth 12–14 μ .

Habit.—Stagnant rain-water pools.

34. *M. tortuosum* Stokes

(Text-Fig. 48)

Pascher and Lemmermann, 1913, p. 160, fig. 322; Walton, 1915, p. 405, pl. 22, fig. 11.

Body S-shaped; posterior end gradually drawn out into a more or less pointed process. Pellicle firm. Flagellum about $\frac{1}{2}$ as long as the body. Paramylum elongate; nucleus median.

Length 40–80 μ ; breadth 3–10 μ .

Habit.—Stagnant ditches; Amberpet.

Skuja thinks (1948, p. 211) that the two species, *M. falcatum* Zach. and *M. tortuosum* Stokes cannot be separated from each other only on the basis of their cell-shape, but in my collections, I have always found the latter species quite smaller in size than the former.

Peranemaceæ

Genus *Petalomonas* Stein

35. *P. alata* Stokes

(Text-Figs. 43–44)

Pascher and Lemmermann, 1913, p. 167, fig. 348; Walton, 1915, p. 412, pl. 23, fig. 13; Shawhan and Jahn, 1947, p. 186, fig. 11.

Body oval, broader posteriorly. Longitudinal carinæ four, two dorso-lateral and two ventro-lateral. Wide shallow furrows present on dorsal and ventral surfaces. Flagellum more or less twice the length of the body.

Length 20–30 μ .

Habit.—In a pond; Nacharum.

Genus *Notosolenus* Stokes

36. *N. Skujai* spec. nov.

(Text-Figs. 45–47)

Corpus ovoideum; apex posterior late truncatus, tenui prominentia hyalina ornatus. Surculus medius dorsalis latus, circiter $\frac{2}{3}$

diametri totius corporis .Flagella duo; flagellum primum $1\frac{1}{2}$ longius corpore, secundarium vero multo brevius, circiter $\frac{1}{3}$ longitudinis primarii, atque pone ductum. Pellicula levis; quæ in cellula continentur in regione extrema posteriore sunt hyalina; vacuolum laterale, locatum in anteriore parte; nucleus positus ad apicem latiore infra medium.

Longus 12.5–15.5 μ ; *latus* 11–12.5 μ .

Habitat in lacu piscium seminario ad Hussain Sagar.

Body ovoid; posterior end broadly truncate with a slight hyaline prominence. Dorsal median furrow broad, about $\frac{3}{4}$ diameter of the body. Flagella two; the primary flagellum $1\frac{1}{2}$ of the length of the body, the second much shorter, about $\frac{1}{3}$ the length of the primary and trailing behind. Pellicle smooth; cell-contents hyaline in the extreme posterior region; vacuole lateral, anteriorly placed; nucleus at the broader end below the middle.

Length 12.5–15.5 μ ; breadth 11–12.5 μ .

Habit.—Fish-breeding pond; Hussain Sagar.

The flagellate closely resembles the American species *N. orbicularis* Stokes in its shape but differs from it in having a broad truncate end with a prominence. It also differs from it in being larger in size.

This is probably the only record of the genus from India.

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EFFECTS OF VARIOUS LEVELS OF NITROGEN ON THE VEGETATIVE GROWTH AND EAR EMERGENCE OF RICE PLANTS

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INTRODUCTION

CERTAIN amount of work has been done on the effects of different levels of nitrogen on the metabolic activity, growth and yield of cereals like barley (Gregory and Crowther, 1928, 1931) and wheat (Thelin and Beaumont, 1934; Singh and Singh, 1940; Lal and Yadav, 1949). Nitrogen is one of the major essential elements for plant growth. Though the effects of different types of nitrogen, *e.g.*, ammonium nitrogen or nitrate nitrogen has been studied on the metabolism and growth of rice plants (Asana, 1945; Dastur and Malkani, 1933; Dastur and Pirzada, 1934; Espino and Estioke, 1931; and Willis and Carrero, 1923), there is very little work on the effects of different levels of nitrogen on its growth and development.

The aim of the present investigation is to determine the vegetative growth and ear emergence of rice plants when nitrogen at different levels is applied at different stages of growth.

MATERIAL AND METHODS

A pure variety of rice, Co 16 (a cross between variety Geb 24 and Adt 10) was obtained from the Central Rice Research Institute, Cuttack. After a preliminary selection for uniformity, the grains were soaked in water for 36 hours and sown in sand on July 25, 1953 in seed-bed pots. On September 14, the seedlings were transplanted to glazed pots which contained 30 lbs. of well-washed river-bed sand at the rate of 8 seedlings per pot. The nutrient solution was supplied through a small earthenware pot placed at the centre of each glazed pot. The usual method of collecting the drained solution from time to time and re-adding it was adopted. The nutrient solution used in this case was that of Gregory and Richards (1929) as modified by Sircar and Sen (1941). The full dose of nitrogen consisted of as follows:—

	g. of salt per pot
NH_4NO_3	3.00
$\text{Na}_2\text{HPO}_4, 12\text{H}_2\text{O}$	2.52
$\text{MgSO}_4, 7\text{H}_2\text{O}$	1.27
K_2SO_4	1.85
$\text{CaCl}_2, 6\text{H}_2\text{O}$	0.37

As NH_4 ions are useful at the early stages and NO_3 ions at later stages, NH_4NO_3 was chosen as the source of nitrogen in the culture solution. Traces of ferric chloride and manganese sulphate were also added. Four levels of nitrogen were used in the present investi-

gation for nitrogen deficiency. Each such pot received 1/3, 1/9, 1/27 and 1/81th of the full amount of ammonium nitrate thus receiving 1.00, 0.33, 0.11 and 0.037 g. per pot. The total amount of the nutrients was added in three equal instalments on September 23, October 16, and November 28.

EXPERIMENTAL RESULTS

The data on number of tillers and leaves, height of the individual plant and the time to ear emergence under each level of nitrogen were recorded as usual and are presented in Table I.

TABLE I

Number of tillers, green leaves, height per plant and time from sowing to ear emergence under different levels of nitrogen

(Average of 16 Plants)

Dates of record		Full N	1/3 N °	1/9 N	1/27 N	1/81N
			Number of tillers per plant			
3-10-1953	..	1.31	1.37	1.00	1.00	1.00
19-11-1953	..	1.50	1.62	1.31	1.06	1.12
9-12-1953	..	9.93	3.62	1.50	1.31	1.37
			Number of green leaves per plant			
3-10-1953	..	6.75	6.12	4.81	4.75	4.87
19-11-1953	..	10.81	8.12	4.81	3.93	4.70
9-12-1953	..	33.62	12.50	4.70	3.56	3.60
			Height per plant in cm.			
3-10-1953	..	39.44	38.48	35.15	39.81	35.00
19-11-1953	..	57.18	51.78	50.08	45.21	47.20
9-12-1953	..	66.33	62.66	60.53	54.30	53.74
			Days from sowing to ear emergence			
		126.75	126.50	125.66	125.68	124.06

A study of Table I leads to the following salient points:—

1. After the addition of the first dose of the nutrient solution, no marked difference in the production of tillers has been brought about although the number of tillers in the full and one-third series is quantitatively more than those in the lower series. After the addition of the second dose there has been augmentation of tillering in all the sets. However, the distinctive effect of the higher doses was main-

tained. The addition of the third dose of nutrients has brought about remarkable changes. In the full nitrogen series is exhibited a luxuriant production of tillers quite in contrast to the poor and insignificant increase in their number in the lower series.

2. The number of leaves produced per plant in the full and one-third series shows a conspicuous difference from those in the lower levels. The addition of the second and third doses has brought about quite a significant increase in the leaf number in the full nitrogen series which far surpasses those in the others. The other remarkable feature is the gradual increase in the number of green leaves with every addition of a fresh dose of nutrients in the full and one-third series. In contrast to those in the lower levels even with addition of second and third doses of nutrients there has been yellowing and drying out of the normal green leaves formed at the young stage.

3. The addition of each fresh dose of nitrogen at all levels brings about a gradual increase in plant height. In higher levels, however, the height of plants throughout their ontogeny are well distinguished from those plants of the lower level.

4. The time to ear emergence has not been materially affected in the plants receiving lower levels of nitrogen from those in the full nitrogen series.

DISCUSSION

The data presented above clearly indicate the essential role of nitrogen in the vegetative growth of the rice plants. Although by decreasing the nitrogen level, not much appreciable effect is noticed in the number of tillers at the early stages of growth, very marked differences are noticed with full nitrogen after the third application. At lower nitrogen levels, however, the effects are not much. This indicates that early application of full nitrogen though might not have any effect immediately has a far-reaching influence in determining the nature of tiller growth when the application of the total amount is completed at a later stage. Furthermore, nitrogen at all levels whenever applied has uniformly increased the height of the plants, but the most outstanding effect is on the development of green leaves, the real assimilating portion of the plant. Low nitrogen definitely retards the growth of green leaves and causes their deterioration; but full nitrogen has always the beneficial effects of promoting and maintaining the green leaves of the plants. Another aspect which becomes clear is that when the plants are supplied with nitrogen at lower levels in the beginning, subsequent applications in same doses bring about little improvement in the general vigour. From all these it appears that full doses of nitrogen are not only necessary at a later phase of growth but are required at early stages for the better utilisation of further quantities later and a full supply of nitrogen is indispensable for the better vegetative growth. Although increased doses of nitrogen in the nutrients results in larger plants, the time from sowing to ear emergence is unaffected. A similar dull effect of increased levels of nitrogen on the time to flower initiation is reported in Petkus rye by Purvis (1934).

SUMMARY

Rice plants were grown in sand culture under different levels of nitrogen, e.g., Full, 1/3, 1/9, 1/27 and 1/81 N. Nitrogen was supplied in the form of NH_4NO_3 thrice during the life-cycle. Increased levels of nitrogen had no effect on time to ear emergence but luxuriant growth by way of augmentation of tiller number, promotion and maintenance of green leaves and elongation of the stem axis occurred at higher levels of nitrogen particularly at the full and the one-third doses. Conspicuous differences in the general vigour between the low-level plants and those of the high-level ones were observed after the third, i.e., the last instalment of application of the nutrients.

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PHOTOPERIODIC RESPONSE OF SOME EARLY VARIETIES OF RICE OF BIHAR

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BESIDES their use as a method of synchronising, for purposes of hybridisation, the flowering time of rice varieties, whose flowering duration differs widely, photoperiodic experiments throw much light on the behaviour of individual varieties to day-length treatments. In the course of hybridisation programme during the last three years, aimed at evolving early-maturing heavy yielders for different agro-climatic conditions of the State, it was observed that some of the 'aus' (short duration) varieties showed a tendency towards delayed flowering when the normal day-length was reduced. (Roy and Subramanyam, 1955). In view of this, an investigation was undertaken in this laboratory in which different 'aus' selections were studied under an 8-hour day-light and the present communication records the response of 25 early maturing autumn varieties to short-day treatment.

MATERIALS AND METHODS

Pure pedigree seeds of the varieties selected from single ears were sown in earthen pots of 10"×10", in 3-replicates well mixed with 3 parts of soil and 1 part of compost. Germination was complete in a week and the seedlings were thinned to one in each pot, after a week of germination. Ammonium sulphate and single superphosphate at the rate of 2 oz. for each pot was applied as top-dressing. Treatment of short days was commenced when the seedlings were 30 days old. The duration of treatment was 8 hours light period alternating with 16 hours dark period. This was achieved by removing the pots to a dark chamber at 13 hours everyday till ear emergence was complete in all the tillers of individual plants. The control plants were given normal day-light in the open. All other conditions except short-day treatment were kept, as far as possible, identical in both the cases. The seasonal day-length during the course of this investigation was 14 hours.

RESULTS AND DISCUSSION

The data presented in Table I show the response of the varieties to 8 hours short-days.

It can be seen from the table that the response of the rice varieties to short-day light conditions is greatly a varietal character (Kar, 1946; Misra, 1953-55; Sarkar and Ghosh, 1947; Sarkar and Parija, 1949). An application of short photoperiods of 8 hours shows that even 'aus' varieties, which are periodically-fixed varieties, could be made to flower earlier by controlling the day-length (Saran, 1945). In this experiment

TABLE I*
Date of sowing 17-6-1954. Date of treatment commenced 17-7-1954.
Showing the flowering duration and the response of rice varieties to short-day treatment
 (+ earliness, - lateness)

No.	Variety	Date of flowering		Number of non-fertile tillers		Number of fertile tillers		Flowering duration in days		Response in days
		Treated	Control	Treated	Control	Treated	Control	Treated	Control	
1	Browngora	28-8	29-8	7	8	5	6	73	74	+ 1
2	Chapra	14-8	19-8	12	14	9	12	59	64	+ 5
3	Sona	13-8	20-8	13	16	11	13	58	65	+ 7
4	Nawadah	15-8	23-8	12	16	8	12	60	68	+ 8
5	Sathika	14-8	23-8	10	12	7	8	59	68	+ 9
6	Ch. 45	12-8	22-8	8	10	5	7	57	67	+ 10
7	Ch. 1040	15-8	25-8	13	10	4	8	60	70	+ 10
8	Ch. 42	13-8	23-8	14	10	11	8	58	68	+ 10
9	Deogarh	11-8	21-8	14	10	7	8	56	66	+ 10
10	Whitigora	14-8	25-8	9	14	7	6	59	70	+ 11
11	Ch. 1007	13-8	25-8	14	10	8	8	58	70	+ 12
12	Ch. 1039	11-8	23-8	14	10	6	9	56	68	+ 12
13	Ch. 47	17-8	12-9	9	12	6	10	62	88	+ 26
14	Ch. 41	15-8	3-9	9	10	5	8	60	79	+ 19
15	Kolaba	14-8	3-9	8	14	7	10	59	79	+ 20
16	Ch. 18	17-8	13-8	10	4	6	2	62	58	- 4
17	Ch. 62	28-8	23-8	8	10	5	7	73	68	- 5
18	Ch. 2	12-8	7-8	12	14	8	8	57	52	- 5
19	Ch. 10	23-8	18-8	10	12	7	9	68	63	- 5
20	Ch. 43	11-8	5-8	14	14	7	10	56	50	- 6
21	Blackgora	18-8	11-8	11	12	5	6	63	56	- 7
22	Ch. 63	15-8	6-8	12	14	8	10	60	51	- 9
23	Ch. 4	28-8	20-8	5	4	4	3	73	65	- 8
24	Hungarian	2-8	2-8	9	12	6	10	47	47	Nil
25	Sarguja	13-8	13-8	7	10	5	9	58	58	Nil

* Average of three replicates. There was a difference of ± 1 day in the flowering between the replicates.

15 varieties show induced earliness in flowering of which *kolaba*, Ch 41 & CH 47 show 20, 19 and 26 days, respectively, in flowering duration. Of the 8 varieties which show a delayed flowering, CH 4, CH 63, *Blackgora* and CH 43 prolong the time of ear emergence by 8, 9, 7 and 6 days, respectively. *Hungarian* and *Sarguja* are the two varieties that show no response to the treatment.

On the basis of the response to short-day treatment, these 'aus' varieties can be grouped under the following heads: (i) varieties that show a positive response, *i.e.*, induced earliness, (ii) varieties that show a negative response, *i.e.*, induced lateness and (iii) varieties that are neutral, *i.e.*, neither delay nor earliness in flowering. The response, both positive and negative, differ greatly with varieties, inasmuch as the normal flowering duration of the varieties differ from each other.

Similar results that 8 hours short-days bring about a delayed effect in the flowering time of early maturing rice varieties, were obtained by Sarkar and Ghosh (1947) in *Charnock* and *Panbira* though Sarkar and Parija (1949) did not get any delaying effect in *Jhanji* 34 and *Bhutmari* 36, the varieties of Bengal, by the application of similar treatments. Misra (*loc. cit.*) also got similar delaying effect in the varieties of Uttar Pradesh. Kar (*loc. cit.*) in his study of photoperiodic reaction on two summer and eight winter varieties of rice, observed that high temperature associated with short-days was inductive to earliness and low temperature or long days produced retardation in flowering. The findings of Misra as well as the results of the present communication, show that in paddy grown throughout their life-cycle under naturally prevailing high temperature, short-days did not invariably induce earliness in all the varieties of rice but rather they have greatly prolonged the time of ear emergence in some of the varieties. The photoperiodic behaviour of these short-durated varieties stand quite in contrast to the long durated varieties [Sarkar, (1942), Saran (*loc. cit.*), Roy and Subramanyam (*loc. cit.*)] where considerable earliness is obtained by the application of 8 hours day-length treatments. Thus the response to photoperiodism in rice is largely a varietal characteristic.

The results also indicate that two of the 'aus' varieties show no response to short-days. This period acts as the period of minimum flowering duration required by that variety to attain the flowering phase. No reduction in the flowering duration of these varieties is possible by control of day-light.

The flowering behaviour of these varieties under 8 hours short-days shows that short-durated varieties can be grouped as 'short-day', 'long-day' and 'day-neutral', when the normal day-length is shortened. Varieties that show a tendency to delayed flowering give a clue to their possible utilization as varieties that can be grown in summer months, when the day-length is long. It may be of interest to record that *Blackgora*, one of the varieties showing delayed flowering, has long been in cultivation during summer months in the Chotanagpur range of the State.

SUMMARY

Studies on the photoperiodic behaviour of 25 'aus' varieties of rice under an 8-hour short-day length show that they can be grouped into (i) short-day, (ii) long-day or (iii) day-neutral depending on the early, late or no response to short-days. The usefulness of classifying the short durationed rice varieties on the photoperiodic behaviour is discussed.

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FACTORS IN THE DISTRIBUTION OF TEAK IN MADHYA PRADESH

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INTRODUCTION

BEGINNING with the description of the teak forests of M.P. by Brandis, about the middle of the last century (*cf.*, McDonald, 1940), a number of papers describing the ecology of teak were published. The position prior to 1920 was summed up by Troup (1921). Later Vahid (1931), Hewetson (1941 and 1951), Kulkarni (1951), Kadambi (1951) and Puri (1951) published short accounts of the distribution of the species with reference to climate, surface geology and soils. Most of these observations were based upon the field behaviour of the species and only in one or two cases detailed chemical analysis of the soils were undertaken. The only account of the soils of teak plantation is by Griffith and Gupta (1947). They established a correlation of teak quality with $\text{SiO}_2/\text{R}_2\text{O}_3$ ratio, aspect, depth of permanent moisture availability and dispersion coefficient. Their data showed that a higher amount of bases in the soils was associated with better quality teak. This they felt is to improve soil conditions and as such paid lesser attention to them.

From the ecological study of a mixed teak forest in M.P., the author (Bhatia, 1954) has again shown a correlation between teak distribution and basic soils. The other factors that favour teak in these forests are less of biotic interference and the absence of aggressive competing species. The present Study was, therefore, extended to some well-known teak forests of the state in order to test the general validity of the above correlation. The area included are Allapalli Sub-Division (Chanda Division), Bori Reserves and Khali Range (Hoshangabad Division), Punnsa and West Khalibhet Ranges (Nimar Division), Hirdaygarh (Chhindwara Division) and Ramna Reserves, Bhandra Range, and Damoh Range of the Saugar Division.

METHODS OF STUDY

Vegetational analysis.—For the floristic study of teak stands ten quadrats of 7.5×7.5 m. were laid around the pit from which soil samples were collected. Analytical data were obtained for frequency, abundance and cover. The results were expressed as percentages. These values were, however, not of much significance as the forests are disturbed either by the selective felling of other tree species or by the adverse effect of biotic exploitation. For the interpretation of the results, therefore, quality growth and frequency distribution of representative stands have been utilised.

Soil analysis.—Soil samples were collected at a depth of 15 cm. when a single sample was required and from various depths, *i.e.*, 0, 15, 30, 60, 90, 120 cm., when profile study was made. The samples were air dried, ground in a porcelain mortar, passed through a 1 mm. sieve and were stored in glass bottles. Very often samples were required to be brought from great distances, sometimes as much as 800–960 kilometres. In such cases about 30 to 50 gm. of the soil was taken in a specimen tube. A cork previously lined with butter-paper to prevent the absorption of moisture by the dry cork, was tightly fitted. The corked end was then sealed off in the field with wax.

The following methods were followed for the analysis of the soils:

Moisture content.—Determined by oven drying of the soil at 105° C. The results were expressed on basis of the oven dry weight.

pH.—Determined on 1:5 soil suspension by a pH meter.

Organic carbon.—Estimated by the method outlined by Robinson, McLean and Williams (1929).

Nitrogen.—Kjeldhal's method as outlined by Piper (1944).

Exchangeable ions.—Soils were leached with N ammonium chloride solution. The methods outlined by Piper (1944) were followed for the estimation of calcium, magnesium and potassium. Calcium was precipitated as oxalate and estimated by KMnO_4 titration. Magnesium was estimated by phosphate method and reported as pyrophosphate. Potassium was precipitated by the cobaltinitrite method. The values reported for potassium could not be repeated with satisfaction and are, therefore, not included in the present account.

Phosphates.—Total available phosphates were extracted by carbon dioxide in a 2% soil suspension (Puri and Asghar's method 1936). The blue colour was developed by stannous chloride method of Chapman (1932) and was compared by Helige Chromatron.

CLIMATE, GEOLOGY AND VEGETATION

1. Hoshangabad Division

Bori Reserves.—These lie in the valley of the Bori River, a tributary of the Nerbada, flowing towards the west. The valley is closed, extending over 130 sq. kilometres in an elongated boat-shaped area, with a higher elevation towards the east.

The underlying rocks are the Bijori beds of the Lower Gondwana, over which are laid a thick deposit of Panchmari sandstones of the middle Gondwana age. The general topography of the area is interrupted by trap intrusions of the nature of dykes and sills. These form low hillocks, of not more than 150 m. high. Thick sedimentary deposits of recent origin are found in the valleys flanking the river courses of the Sonbhadra and Bori.

Detailed meteorological data are not available for the area but it seems that the rainfall is well over 250 cm., with a progressive decrease towards the west. The absolute maximum temperature recorded in

May 1942, is 40° C. In winter, frost is liable to occur in depressions [Kulkarni (in press)].

The Bori Reserves constitute the first forests in India to be systematically reserved and fire protected (1859 and 1864).

McDonald (1940) in an article on Bori gave a vivid account of the forests through 81 years of protection. The present historical resume is largely based on information provided by him.

Brandis described the forests in 1869 and 1872 (cf., McDonald, 1940), as that of teak and bamboos, but the proportion of the latter had decreased by that time considerably. This was attributed to the spasmodic widespread flowering of bamboos, in the interval of which the establishment of teak seedlings took place.

Improvement fellings were carried out in 1869 and 1875 when mature teak and tinsa (*Pterocarpus marsupium*) over 46 cm. girth were removed.

The first Working Plan was introduced in 1897 according to which the blanks, in areas where fellings were executed, were filled up with seedlings of teak. Bamboos were not very aggressive then.

The Working Plan of 1926 indicated an increase in the percentage of teak; regeneration of teak seedlings was good in areas where the mature and malformed trees were removed.

Kulkarni's plan of 1948 divided the forests into the following types:—

1. Moist miscellaneous type.
2. Mixed type with *Terminalia tomentosa* and *Anogeissus latifolia*.
3. Lower quality mixed type with stunted teak.
4. Good quality teak on trap.
5. Lower quality teak with undergrowth of *Lantana camara*, *Petalidium* and grasses.
6. Alluvial teak.

Evidently, the types were based upon quality classes, associate species and soil types.

It is worthy of note that Bori forms the southern limit of Sal (*Shorea robusta*) and a few stray trees of Sal may be found on quartzites in moist pockets.

Kheli Range (Chougan Fort).—This teak forest is situated on the north slopes of the Satpura ranges just at the place where they arise abruptly from the plains of Narsinghpur.

The outer fringes are composed of the Bagra conglomerates; towards the south they are replaced by Jabalpur sandstones of the upper Gondwana. Igneous rocks of the nature of lava flows irregularly break up the area while at places gneisses and calcareous crystallines are also found.

No climatic data are available for the area but it is expected that it would approximate the general conditions of the state with possibilities of greater rainfall.

The forest is of a mixed type with varying proportions of 4th quality teak and is worked under 'coppice with reserve' system.

2. South Chanda Division

Allapalli Sub-Division.—This reserve, extending over 190 sq. kilometres, is situated in the extreme south of the State in the Chanda Division, 96 kilometres away from the border of Hyderabad.

On topographical basis the area is divided into two parts. The plains, consisting for the most part of deep alluvial deposits of clayey loams and sandy soils, with a general height of about 125–52 metres. The hills rising upto 486 m. are made up of granites, metamorphic gneisses and quartzites.

Although no proper meteorological data are maintained for the Reserve the hilly tracts receive an annual rainfall of 177 cm. approx. according to McDonald and Majumdar (1952). The mean maximum and minimum temperatures for the years 1936–45 were 33° C. and 21° C., for Chanda. The water table in summer for the following places in the plain region is as follows:—

Rest House	..	..	5.80 metres
Talwara	..	..	7.20 „
Taradev	..	..	6.00 „

The forest was acquired from the local Zamindars in the year 1873. The historical details of the forest at Allapalli have been very well summed up by Hewetson (1950) and the present account is freely drawn from that source. The first comprehensive account was written by Brandis in 1866–77. He distinguished two types of forests; the Hill and the Plain types. Brandis described the Hill type at Bhimaram as a Bamboo-Teak type with a scattered distribution of *Dalbergia latifolia*, *Mitragyna parvifolia* and *Pterocarpus marsupium*. On the plains, three types were distinguished. The stream-bank type with *Terminalia tomentosa*, *Diospyros melanoxylon*, *Adina cordifolia* and *Mitragyna parvifolia*, with varying proportion of teak. The high ground type with inferior species associated with teak. The third type, known as the teak forest type, has teak as dominant species. Here teak is associated with *Terminalia tomentosa*, *Dalbergia latifolia* and a number of other species. Clutterbuck's descriptions in 1896 showed that except for the north plain area the other forest did not materially change. The descriptions provided by McDonald and Majumdar (1952) showed a significant change in the Bhimaram Hills where in 75 years the percentage of teak increased, regeneration became sparse and *Petalidium* increased in abundance. On the plains teak is the dominating species but reproduces rarely. The alluvium deposits provide the optimum conditions for good teak when drainage is good. In water-logged areas the forest floor is clothed with grasses.

5. Sagar Division

Sagar.—It is situated in the extreme north-west corner of the State and consists mainly of the black soil tract area at about 300 m. above sea-level.

The drainage is provided by the rivers Sonar, a tributary of the Jamuna, flowing north, Bewas, Bina and Betwa flowing eastward.

The forested tracts of the division rest mainly upon the Deccan trap hills, Vindhyan sandstones and shales, crystalline limestones, Lameta beds, Bundhelkhand complex and on the alluvium deposits.

The average rainfall recorded for the division is from 100–120 cm. There is a slight decrease towards the north. The average monthly minimum and maximum temperatures are 11.5° C. and 25° C. in January, 25.5° C. and 40.5° C. in May and 23.5° C. and 28° C. in July according to Russel (1906). Slight frost may occur during the cold weather.

Four main types of the forests are distinguished according to Russel (1906):—

1. Teak forest.
2. Mixed teak forest.
3. Mixed miscellaneous forest.
4. Bamboo forest.
5. *Butea monosperma* forest.

According to Champion's classification (1938) of the forest types, Sagar has a mixed tropical dry deciduous forest. Over a greater area of the division where the forest is left unprotected high biotic pressure and intense grazing have reduced the forest to a miserable state. It is not infrequent to find open scrub jungles over such regions.

Ramna Reserve.—It is a small forest reserve on the banks of the river Sonar with an area of 1,200 hectares. The ground on most of the area is level and is cut by ravines and nallas at many places. Towards the south-west is a hill range running across the reserve and is composed of Vindhyan sandstones and shales.

The soil is derived, for the most part, from the alluvium deposits and is usually a sandy loam with fair distribution of lime nodules or at places it may be clayey. The hill supports a thin cap of soil usually derived from the Vindhyan sandstones and shales.

Shahgarh (Banda Range).—It is situated on a complex geological area—the Bundhelkhand complex consisting of gneisses, limestones, sandstones, hametite, etc.

Teak extends just a bit north of this place towards Jhansi Division of Uttar Pradesh. The northern limit of the distribution of the species is confined to these areas.

INTERPRETATION OF THE DATA

1. *Chemical Characteristics of the Soil and Teak Distribution*

pH.—The pH values (Table VII) obtained for the different teak forests show a definite correlation. Most soils that are neutral or basic support good quality teak. The frequency distribution of teak tends to become more sparse and growth deteriorates with the fall of soil pH to below 6.0. Such acid conditions are usually encountered in the soils derived from the Gondwana sandstones (Hirdaygarh 2-3-5, Bori 2 A, Kheli 4), Haematite rocks (Banda 3), Quartzitic rocks producing shallow soils (Bori 6), and the thin cap of residual soils on the plateau tops of basaltic and sandstone origin (Sagar 3 and Ghatera 2). The pH values in the different sections of the profile also vary significantly (Table VIII). Soils supporting good teak are characterised by an increase in the pH value in the sub-soil region while those supporting a poorer quality teak maintain uniform acid condition.

Calcium.—The correlation for calcium (Table IX) follows the same general line as that of pH, in fact the exchangeable calcium of the soil itself determines the pH of the soil to a good extent. Most soils with good teak register values above 0.3%. The species grows well on highly basic substrata with exchangeable calcium exceeding 2.4% (Ramna 2, West Kalibhet 1). The number of samples with exchangeable calcium above 1% is fairly large. With decrease in the exchangeable calcium in the soil a corresponding deterioration of quality sets in and the distribution of the species over such areas is seriously checked. Usually on such situations only a few isolated malformed individuals may be found or teak may even be completely absent.

It is interesting to note that at Allapalli (Nos. 2-4-11-12) some of the best teak forests in M.P. are found on soils with exchangeable calcium oxide slightly below 0.3%. These soils are derived from metamorphic gneisses and quartzites. Good teak growth on such soils is due to other soil conditions, like aeration, soil temperature and moisture, being favourable.

High exchangeable calcium is usually associated with alluvial soils. Here are found a combination of favourable factors and very often some of the best teak in M.P. is found growing upon them. (Ramna 2, West Kalibhet 1, Bori 1 and Allapalli 5). The profile in such cases are maintained at a higher moisture level and are very well aerated. Very often the profiles are studded with lime nodules. Calcareous situations in the drier parts (Punnasa 2, Banda 2) do not support a higher quality teak nor does the distribution become more frequent. Soils derived from basalt are usually rich in basic minerals and support good teak (Bori 2, 4, 9; Sagar 1, 2; Hirdaygarh 1, 4). Vindhyan sandstones have varying proportion of calcium and teak growth very often depends upon the amount of the element present. At Ghatera (2) the growth is, however, poor. On acid soils of the Gondwanas exchangeable calcium is usually found far below the amounts conducive to good teak growth. The species is usually absent over such areas. However,

on the conglomerates of the Gondwana system, Bagra conglomerates at Kholi I, and Vindhyan system (Punnasa 5), the distribution of the species becomes more frequent and the percentage abundance is increased considerably. In such cases the matrix, within which the rock particles are studded, has a higher base status. It is evident, therefore, that much of the heterogeneity in the distribution of the species can in a great part be attributed to this element. The critical exchangeable calcium concentration above which teak seems to do well is in the neighbourhood of 0.3%.

The distribution of the element in the profile fully substantiates the above view (Table X). A good class of teak forest is supported on soils with basic substrata. In strict contrast poor quality teak is almost invariably found to be associated in the Satpuras, with acid conditions developing within the profile.

Magnesium.—Magnesium values follow the same general line as pH and calcium—higher values associated with good teak growth and higher frequency distribution (Table XI). The distribution of the element in the profile shows only a slight increase in the sub-soil region (Table XII) in contrast to the higher values obtained for calcium. This is true for all types of teak forests.

Phosphate.—A direct correlation is again found in the values of soil phosphate and teak distribution (Table XIII). At the northern limit, the species shows a preference for the trap soils. Besides the high-water-retaining capacity of these soils it is possible that higher abundance and greater frequency distribution may in part be due to the presence in these rocks of a phosphate mineral, apatite (phosphate of lime).

Moisture.—Moisture content of the soils does not, however, afford a good basis for comparison unless it is determined all the year round. Comparing the summer values only it can be shown that a lowering of the quality class sets in with the fall in the moisture content of the soils. It is important to remember that the fall in the moisture content is in many cases due to the loss of the top soil, low water-holding capacity, increase in the surface run off, etc., than to the low amount of rainfall such areas receive.

The distribution of the species in relation to moisture has previously been emphasized by Champion (1938). He regards teak forests to be borne on soils that are physiologically more moist. With drought the percentage of miscellaneous species increases. Hewetson (1941) has likewise argued that the preference teak shows for trap soils is due to their ability to retain moisture. Quite in line with these observations it may be stated that the best growth of teak at Sagar, an area forming the northern limit of the species, is obtained at Ramna and Ghatera on river alluvia. The distribution closely follows these deposits for a long way north into the more arid regions.

Many of the local discontinuities of the species can in part be alluded to its moisture relations. In the northern semi-arid regions it follows areas with more moist soils, with increasing dryness teak is

replaced by thorny shrubs. In the more moist south, on the other hand, teak flourishes in well-drained areas and is generally replaced by semi-evergreen miscellaneous species in water-logged habitats.

Organic matter, Nitrogen and C/N.—The organic matter of the soils for the various teak forests does not show any significant difference, nevertheless, they are intimately related to soil fertility and as such they may have an indirect effect. Likewise the values for nitrogen and C/N show no definite correlation.

2. *Chemical Characteristics of the Soil and Natural Regeneration of Teak*

Correlation between the available mineral contents of the soil and teak regeneration is found only in the lower ranges of some of the soil characteristics studied. Thus it can be shown that most soils under the range of pH 6.0–6.5 are poor for regeneration. In many cases where regeneration has failed the causal factors are conditions of water-logging, dense shade, especially under low bamboo clumps, excessive grazing and frequent forest fires. If samples from such situations are left out then the role of mineral nutrients are more illustrative (5 B of the Tables VII, IX, XI and XIII). Likewise the lower values for calcium and magnesium are 0.3–0.4 and 0.2–0.25% respectively. Phosphorus values determined for the top 6" of the soil show a significant correlation. Good regeneration is supported on soils with phosphorus range of 5–7 mg./100 gm. Below this range natural regeneration appears to suffer.

Values for moisture content, organic matter and nitrogen content offer no practical basis for comparison and in almost all cases studied they are much the same for the two types of forests studied.

It can be seen from the foregoing account that soil acidity resulting from leaching of the bases and deficiency of soil phosphates have been responsible for the absence of natural regeneration. Since these are the very situations which are associated with a poor distribution of the species failure of regeneration seems to be its cause. However, certain other reasons seem to be responsible for the absence of natural regeneration in a good teak forest and on areas with favourable soil characteristics. Such areas are indeed very many and include Allapalli 4, 5, 10, 12; Nimar 2; Ramna 1; and West Kalibhet 1. The standing teak in all these cases are of top classes.

Champion and Griffith (1947) have remarked that the local failure in natural reproduction is due to "purely local unfavourable micro-climate and soil climate". A few such situations are listed below:—

1. Water-logging. In depressed areas, with impeded drainage, grasses like *Imperata* sp. become very aggressive and regeneration of teak becomes impossible. Besides, the seedlings may suffer from excessive moisture and their roots may rot (Troup, 1921).
2. In extremely dry areas profuse growth of grasses creates unfavourable conditions. Usually they are heavily grazed and the frequent forest fires may destroy the young seedlings.

3. Dense shade developed usually under the low crown of bamboo clumps effectively checks regeneration. It has been seen at Ramna that old stumps do not regenerate coppice shoots under deep shade.
4. Excessive opening of the forest canopy may lead to preponderance of shrubby vegetation which checks teak regeneration.
5. Grazing also checks regeneration but its effect is indirect since the leaves of teak are not much relished by animals (Ann. Rep. of W. P. & Resh. in C.P. and Berar, 1926-27).
6. Fire. In very dry forests the young seedlings are susceptible to fire injury. However, in moisture regions beneficial effects of the forest fires have been recorded (Ann. Rep. of W. P. & Resh. in C.P. and Berar, 1927-28).
7. Perhaps a more direct explanation of the local failure might be observed during abnormal years. Excessive drought in 1928-30 has resulted in the total absence of seedlings at Jabalpur, Narsinghpur, Damoh and Akola divisions. At Akola even coppice shoots failed to appear (Ann. Rep. of W. P. & Resh. in C.P. and Berar, 1929-30). Normal years with good rains and favourable climatic conditions persisting long enough and conducive to good growth of the seedlings have in many cases resulted in patches of teak appearing within such areas. Likewise, the "abnormal frost of 1905 did much damage in parts of the Peninsula". The poles were killed at the top or down to the ground level (Troup, 1921).

CONCLUSIONS

While the results of the present investigation are discussed elsewhere (Bhatia, in press), one point of particular interest is discussed here briefly. Griffith and Gupta (1947) have shown that there is a deterioration in teak quality and growth on soils with low $\text{SiO}_2/\text{R}_2\text{O}_3$ ratio. Incidentally this is indicative of a laterite exposure within the profile. The lower silica content, the concentration of R_2O_3 and impoverishment of the bases are important characteristics of laterization and all these go hand in hand. Since from the view-point of plant nutrition the important elements that are lost during this process of soil formation are the bases the suitability of such sites can best be ascertained by the presence in the soil of sufficient amount of these elements.

Although the critical lower limits of the concentration of the various elements like calcium, magnesium, phosphorus, pH and moisture are presented, below which the distribution of the species suffers a set-back, there is no proportional increase either in the frequency distribution or quality classes once the critical levels have been passed—a straight line graph cannot, therefore, be expected. Above the critical level the pattern of distribution is maintained by quite a number of other factors, viz., physical characteristics like drainage,

aeration, pore space, and permeability; the presence of aggressive competing species; the adverse effect of local climate like excessive drought and frost and adjustive response to biotic and pyric influences. A detailed analysis of these factors would be interesting and may perhaps explain a good part of the problem.

SUMMARY

Teak stands at Bori, Kheli, Allapalli, Nimar, West Kalibhet, Hirdaygarh and Sagar have been studied.

Their location, climate, surface geology and vegetational features have been described.

Soils were studied for pH, moisture content, exchangeable calcium, magnesium, potassium, total available phosphate, nitrogen, organic matter and carbon/nitrogen.

Positive correlation has been obtained between teak growth and distribution and soil pH, exchangeable calcium, magnesium and phosphate. No significant correlation could be obtained for nitrogen, organic matter and C/N. The moisture relationship of teak shows that the species generally avoids excessive drought on the one hand and water-logged situations on the other.

On acidic soils with low phosphate and low base content regeneration suffers a set-back. But in areas with favourable edaphic conditions the failure of natural regeneration has been alluded to a number of other causes.

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ANNOTATED LIST OF PLANTS

TREES :—

Acacia arabica Willd.
Acacia leucophlea Willd.
Acacia catechu Willd.
Aegle marmelos Corr.
Albizia lebbek Benth.
Albizia odoratissima Benth.
Albizia procera Benth.
Annona squamosa Linn.
Anogeissus latifolia Wall.
Anogeissus pendula Edgew.
Azadirachta indica A. Juss.
Bauhinia malabarica Roxb.
Bauhinia racemosa Vahl.
Bauhinia sp.

Boswellia serrata Roxb.
Bridelia retusa A. Juss.
Buchanania lanzan Spreng.
(syn. *B. latifolia* Roxb.)
Butea monosperma O. Ktze.
(syn. *B. frondosa* Roxb.)
Cassia fistula Linn.
Cedrela toona Roxb.
Chloroxylon swietenia DC.
Cleistanthus collinus (?) Benth.
Cordia myxa Roxb.
(syn. *C. obliqua* Willd.,
C. dichotoma Forst.)
Dalbergia paniculata Roxb.
Dendrocalamus strictus Nees.

Diospyros melanoxylon Roxb.
Elæodendron glaucum Pers.
Emblica officinalis Gärtn.
 (syn. *Phyllanthus emblica* Linn.)
Eugenia jambolana Lam.
Feronia elephantum Correa.
Ficus bengalensis Linn.
Ficus glomerata Roxb.
Flacourtia ramontchi L'Her.
Gardenia latifolia Ait.
Gardenia turgida Roxb.
Hardwickia binata Roxb.
Holoptelia integrifolia Planch.
Ixora parviflora Vahl.
Kydia calycina Roxb.
Lagerstræmia parviflora Roxb.
Lannea grandis Engler.
 (syn. *Odina wodier* Roxb.)
Madhuca latifolia (Roxb.) Macbr.
 (syn. *Bassia latifolia* Roxb.)
Mallotus philippensis Muel-Arg.
Mangifera indica Linn.
Mitragyna parvifolia Korth.
 (syn. *Stephegyne parvifolia* Korth.)
Nyctanthes arbor-tristis Linn.
Ougeinia dalbergioides Benth.
Pterocarpus marsupium Roxb.
Phenix sp.
Saccopetalum tomentosum Hk. f. & T.
Salmalia malabarica Schott. et. Endl.
 [syn. *Bombax malabaricum* DC.,
Gossampinus malabarica (DC.)
 Alston]

Schleichera oleosa (Lour) Merr.
 (syn. *S. trijuga* Willd.)
Shorea robusta Gärtn. f.
Sterculia urens Roxb.
Tamarindus indica Linn.
Tectona grandis Linn. f.
Terminalia glabra Wight & Arn.
Terminalia chebula Retz.
Terminalia tomentosa Bedd.
Wrightia tinctoria Br.
Zizyphus jujuba Lamk.
 SHRUBS AND CLIMBERS :—
Carissa spinarum (aut. non. Linn.)
Celestrus sp.
Helicteres isora Linn.
Lantana camara Linn.
 (syn. *L. aculeata* Linn.)
Mimosa himalayana Gamble
 (syn. *M. rubicaulis* Lamk.)
Zizyphus ænopia Mill.
Zizyphus rotundifolia Lamk.
Zizyphus xylopyrus Willd.
 HERBS AND GRASSES :—
Apluda mutica Hack.
Cassia tora Linn.
Colebrookea oppositifolia Smith.
Malvastrum tricuspidatum A. Gray.
Pogostemon plectranthoides Desf.
Petalidium sp.
Sehima nervosum Stapf.
Sida acuta Burm.
Imperata arundinacea (?) Cyrili.
Themeda sp.

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TABLE I
Stands

Description and Composition	Quality	Regeneration	Geology	Topography	Soil*
<i>Bori</i>					
1. (Corresponding Soil No.). Alluvial teak forest near the confluence of the rivers Bori and Sonbadra. <i>Sacopetalum tomentosum</i> forms a co-dominant and other associates include <i>Diospyros melanoxylon</i> , <i>Lagerstræmia parviflora</i> and <i>Aegle marmelos</i> . Regeneration is affected by such adverse factors as frost and grazing. F = 100%. A = 60%. C = 50%.† (For detailed description of teak forests of M.P. refer Bhatia, 1955.)	I	Fair	Alluvium	Level ground with good drainage	Of considerable depth, sandy, light porous and formed by the transported upland soils derived from the sandstones and igneous rocks.
2. A mixed teak stand with bamboos as principal associate. The species include <i>Terminalia tomentosa</i> , <i>Lagerstræmia parviflora</i> , <i>Lannea grandis</i> , <i>Anogeissus latifolia</i> , <i>Diospyros melanoxylon</i> and <i>Albizzia procera</i> . Undergrowth considerably checked by dense bamboo matting; only a few tawny shrubs are found. F = 100%. A = 45%. C = 40%.	II	Fair	Igneous dyke	Top of the mount	Brownish red about 60 cm. deep.
3. Churna Khera. Teak here is stunted although the percentage is high. <i>Lantana camara</i> forms a prominent shrubby layer. The forest floor is clothed with fairly dense grasses like <i>Apluda muteca</i> , <i>Themeda quadrivalis</i> , and <i>Setaria nervosa</i> . <i>Petalidium</i> sp. is the most conspicuous herb. These make regeneration of teak almost impossible. F = 100%. A = 60%. C = 35%.	IV	Nil	Igneous dyke	Plateau top	Brownish, about 60 cm.

4. Compt. No. 50. Preserved for the last six years. Teak-bamboo stand. Forest floor with a dense bamboo litter matting, forest grasses appear only in the regions of clearings. F = 100%. A = 65%. C = 60%.	I	Fair	Igneous dyke	Gentle slope	Brownish red, about 60-75 cm. deep.
6. A mixed miscellaneous forest composed of semi-evergreen species. Sal (<i>Shorea robusta</i>) and teak are found together, though the growth of teak is extremely poor. F = 45%. A = 20%. C = 12%.	IV	Nil	Quartzites	Slopes	Red soil, sandy, of not much depth, extending to about 15-23 cm.
8. Fair regeneration of teak in a non-teak forest.	..	Fair	Pachmarhi sandstones	Lower slopes	It appears that soil from igneous rocks has been transported down.
9. Regeneration of teak in a mixed teak stand. Regeneration confined mostly to the semi-open margins of the dense stand. Associates of teak are much the same as in other areas with igneous rocks. F = 100%. A = 42%. C = 50%.	III	Good	Igneous dyke	Gentle slope	Much like other soils of igneous rocks.
2-A. Base of compt. No. 52. A mixed stand of mesophytes and semi-evergreens with teak completely absent. The more common species include <i>Terminalia chebula</i> , <i>Diospyros melanoxylon</i> , <i>Eugenia jambolana</i> , <i>Mallotus philippinensis</i> , <i>Ficus bengalensis</i> , <i>F. glomerata</i> , <i>Stephgyne parviflora</i> , <i>Schleichera oleosa</i> , <i>Bauhinia racemosa</i> and <i>Maduca latifolia</i> . Undergrowth mainly of <i>Pogostemon plectranthoides</i> and <i>Colebrookia oppositifolia</i> . Regeneration of <i>Diospyros melanoxylon</i> appears to be good.	Absent	Nil	Pachmarhi sandstones	Base of the hill	Sandy porous, light brownish, extending about 60-90 cm. below the surface.

TABLE I—(Continued)

Description and Composition	Quality	Regeneration	Geology	Topography	Soil
<i>Kheli Range</i>					
1. Mixed teak stand on the northern slopes of the Satpuras as they arise abruptly from the plains near Narsinghpur. Three stories in the stand distinguishable; lower story of <i>Gardenia turgida</i> , <i>Flacourtia romanichi</i> and <i>Diospyros melanoxylon</i> ; middle story of <i>Gardenia latifolia</i> , <i>Acacia catechu</i> , <i>Aegle marmelos</i> and <i>Wrightia tinctoria</i> ; the upper story is composed of <i>Tectona grandis</i> , <i>Chloroxylon swietenia</i> , <i>Lannea grandis</i> , <i>Anogeissus latifolia</i> and <i>Kydia calycina</i> . F = 100%. A = 28%. C = 20%.	IV	Good	Bagra conglomerates	Mid-slope	Sandy loam, reddish and of not much dept. Forest floor strewn over with rocks of different origin after the matrix holding them together had disintegrated.
2. Do. Except for greater biotic exploitation.	IV	Good	Bagra conglomerates	Lower slopes	Same as above but for greater soil depth.
3. Mixed teak stand, which has just received silvicultural improvement operations. Most of the shrubs and the herbs have been destroyed. Three layers discernible; lower tree layer of <i>Flacourtia romanichi</i> , <i>Annona squamosa</i> and Bamboos; middle layer of <i>Bauhinia</i> sp., <i>Feronia elephantum</i> and <i>Acacia catechu</i> , while the upper layer is mostly of teak, <i>Anogeissus latifolia</i> , <i>Lannea grandis</i> and <i>Chloroxylon swietenia</i> . F = 80%. A = 15%. C = 9%.	IV	Good	Trap intrusion	Mid slope	Blackish grey, fine loam and of about 90 cm. depth
4. Non-teak stand of semi-evergreens, bamboos and few deciduous species.	Absent	Nil	Jabalpur sandstones	Slopes of Satpuras	..

* See Table VI for soil analysis.

† F = Frequency; A = Abundance; C = Cover.

TABLE II
Stands

Description and Composition	Quality	Regeneration	Geology	Topography	Soil
<i>Allapalli Sub-Division</i>					
2. Teak bamboo stand with good percentage of teak seedlings. Bamboo clumps have been cut down to check its vigour and to permit establishment of teak. Other species include <i>Bauhinia</i> sp., <i>Wrightia tinctoria</i> , <i>Sterculia urens</i> and <i>Schleichera oleosa</i> . F = 100%. A = 25%. C = 30%.	II	Good	Gneiss and quartzites	Top of low mount	Reddish 75 cm. deep and sandy.
4. Compt. No. 76-A. The stand includes the finest crop of teak in M.P. The associates include <i>Anogeissus latifolia</i> , <i>Diospyros melanoxylon</i> , <i>Lagerstræmia parviflora</i> , <i>Cassia fistula</i> , <i>Madhuca latifolia</i> , <i>Schleichera oleosa</i> and <i>Cleistanthus collinus</i> . Undergrowth is not very dense with a few patchy distribution of bamboo clumps. Litters profuse. The area was subjected to improvement fellings in 1914-15 and 1924-25 according to the local forest records. Teak F = 100%. A = 42%. C = 50%.	I	Nil	Metamorphic gneisses	Very gentle slope	About 60-90 cm. deep, sandy loam with a top 30 cm. dark brown and light lower portion.
5. Compt. No. 9-A. Plain teak stand associated with mixed species which include some of the semi-evergreens, like <i>Ixora parviflora</i> , <i>Diospyros melanoxylon</i> , <i>Schleichera oleosa</i> and other species like <i>Terminalia tomentosa</i> and <i>Bauhinia malabaricum</i> . <i>Cleistanthus collinus</i> forms a co-dominant, seedlings of which are specially abundant. Forest floor covered with a thick growth of <i>Imperata arundinacea</i> . F = 100%. A = 42%. C = 32%.	II	Nil	Alluvial deposit (?)	Plain with conditions of water-logging	As above with greater depth.

TABLE II—(Continued)

Description and Composition	Quality	Regeneration	Geology	Topography	Soil
3. Compt. No. 71. Do. with greater abundance of <i>Terminalia tomentosa</i> .	III	Poor	Do.	Do.	Do.
6. Compt. No. 61. A mixed teak stand noted specially for its high percentage of teak seedlings. The miscellaneous species include <i>Anogeissus latifolia</i> , <i>Bauhinia malabaricum</i> , <i>Lagerstrœmia parviflora</i> , <i>Terminalia tomentosa</i> , <i>Cleistanthus collinus</i> and <i>Diospyros melanoxylon</i> . F = 100%. A = 64%. C = 22%.	III	Good	Alluvium deposit (?)	Slight slope with good drainage	Sandy loam, extending to more than 90 cm.
9. Hill type of teak forest, at the base of Bhimaram Hills.	III	Good	..	Lower slopes	..
10. Hill type of teak forest at the top of Bhimaram Hills. Commonly associated with bamboos.	..	Nil	Granite and metamorphics	Upper slopes	..
11. Compt. No. 76-A. As No. 4, with regeneration of teak.	I	Good	Gneisses	..	..
12. Compt. No. 76-A. As No. 4, with no regeneration of teak.	II	Nil	Gneisses	..	..

F = Frequency; A = Abundance; C = Cover.

TABLE III
Stands

Description and Composition	Quality	Regeneration	Geology	Topography	Soil
<i>Purnasa Range</i>					
1. Mixed teak stand with <i>Hardwickia binata</i> as the principal associate. Other species in the area include <i>Anogeissus latifolia</i> , <i>Terminalia tomentosa</i> and <i>Butea monosperma</i> . F = 100%. A = 50%. C = 35%.	IV	Good, mostly by coppice shoots	Trap	Level ground	Black, stiff, clayey and about 60 cm. deep.
2. Mixed teak stand of much similar composition as above except that <i>Diospyros melanoxylon</i> replaces <i>Butea monosperma</i> . F = 80%. A = 50%. C = 20%.	IV	Do.	Crystalline limestone	Do.	Do. with a layer of weathered limestone below.
3. Balwara felling series. Includes mature teak trees that have received silvicultural care for almost 80 years. Teak stand is pure and is perhaps the best in the range. The miscellaneous species constitute 10-15% of the standing crop and includes <i>Diospyros melanoxylon</i> , <i>Anogeissus latifolia</i> , <i>Salmalia malabarica</i> , <i>Boswellia serrata</i> , etc.	III	Nil	Trap	Foot-hill	Mixture formed from trap and transported soils of Vindhyan sandstones; depth about 60 cm.
4. Teak— <i>Boswellia serrata</i> stand. The area bears ample evidence of anthropogenic ravages and most trees are malformed. F = 75%. A = 35%. C = 20%.	IV	Poor	Trap	Slopes	Dark brown, of not much depth.
5. Teak <i>Boswellia</i> stand. Much as above, but the forest is a closed one resulting from better protection. Other species include <i>Sterculia urens</i> , <i>Anogeissus latifolia</i> and <i>Hardwickia binata</i> . R. generation of <i>Boswellia serrata</i> is practically nil. F = 80%. A = 30%. C = 20%.	IV	Fair	Vindhyan conglomerates	Plateau top	Reddish brown, extending not more than 25 cm. below the surface.

TABLE III—(Continued)

Description and Composition	Quality	Regeneration	Geology	Topography	Soil
<i>West Kalibhet Range</i>					
1. Fort Basigarh. An almost pure stand of high quality teak, that has been preserved. The miscellaneous species associated with teak are: <i>Acacia leucophlea</i> , <i>Terminalia tomentosa</i> , etc. The regeneration is poor due to heavy grazing. F = 100%. A = 70%. C = 65%.	II	Poor to nil	Alluvium of the river Tapti	Plain with good drainage	Blackish grey, of great depth with lime nodules in the profile.
2. Ranidev. The stand is situated a little away from the river Tapti, on the black cotton soil. Teak is associated with <i>Terminalia tomentosa</i> , <i>Salmdia malabarica</i> , <i>Diospyros melanoxylon</i> . Litter profuse and forest floor covered with grasses. With better drainage bamboos associate themselves with teak. F = 100%. A = 60%. C = 35%.	III	Fair mostly by coppice shoots	Trap	Plain with good drainage	Black cotton soil of considerable depth.

TABLE IV
Stands

Description and Composition	Quality	Regeneration	Geology	Topography	Soil
<i>Hirdoygarh</i>					
1. A mixed teak stand with <i>Lagerstrœmia parviflora</i> . Other species include <i>Lannea grandis</i> , <i>Zizyphus xylopyra</i> and <i>Buchanania lazan</i> . The area is highly disturbed and forms an open type of vegetation with an approximate cover of about 35-40%. F = 100%. A = 35%. C = 15%.	IV	Fair mostly by coppice shoots	Igneous rocks	Top of the hill	The area is greatly eroded, top soil not more than 15 cm. in many cases almost entirely loss.
2. Mixed forest with greater cover (50-60%) and lesser abundance of teak. The miscellaneous species include <i>Terminalia chebula</i> , <i>Bauhinia</i> sp., <i>Lannea grandis</i> , <i>Diospyros melanoxylon</i> , <i>Ficus bengalensis</i> and <i>Cassia fistula</i> . F = 50%. A = 14%. C = 10%.	IV	Poor	Moturs	Mid-slope. Angle of the slope approx. 60°	Soil of 30-45 cm. depth, sandy, porous and is mixed with the upper soils from the igneous rocks.
3. Mixed miscellaneous stand with almost complete absence of teak. Mixture composed of a number of semi-evergreen species like <i>Bassia latifolia</i> , <i>Eugenia jambolana</i> , <i>Mangifera indica</i> , <i>Terminalia chebula</i> , forming a co-dominant at certain areas. <i>Diospyros melanoxylon</i> and <i>Buchanania lazan</i> ; other species include <i>Lagerstrœmia parviflora</i> , <i>Embellica officinalis</i> , <i>Cassia fistula</i> while the shrub layer is composed mainly of a few scattered <i>Carissa spinarum</i> .	Absent	Nil	Barakars	Base of the hill	Soil light sandy, about 30-60 cm. deep.
4. A mixed teak stand, that bears ample evidence of biotic disturbances. Common associates include <i>Anogeissus latifolia</i> , <i>Diospyros melanoxylon</i> , <i>Terminalia tomentosa</i> and <i>Lagerstrœmia parviflora</i> . F = 100%. A = 45%. C = 30%.	IV	Fair	Igneous dyke	Low mount of not more than 45 m.	Soil brownish, not extending to more than 30-45 cm. below the surface.
5. Mixed miscellaneous stand much as Bori No. 2-A. F = 20%. A = 5%. C = 4%.	IV	Nil	Talchir	Flat top of low mount	Sandy, light, porous, of about 30-45 cm. depth.

A = Abundance; C = Cover; F = Frequency.

TABLE V
Stands

Description and Composition	Quality	Regeneration	Geology	Topography	Soil
<i>Banda Range</i>					
1. Mixed teak stand with <i>Boswellia serrata</i> as its principal associate. Forest composed of a lower tree story of <i>Gardenia turgida</i> , <i>Flacourtia romanitchi</i> and few stray bamboos; middle layer of <i>Gardenia latifolia</i> , <i>Diospyros melanoxylon</i> , <i>Acacia catechu</i> and <i>Saccopetalum tomentosum</i> , while the upper tree layer is made up of teak, <i>Boswellia serrata</i> and <i>Terminalia tomentosa</i> . F = 50%. A = 20%. C = 16%.	IV	Good	Bundhelkhand gneiss	Slight slope	Fairly deep, loamy and dark brown.
2. Mixed teak stand of much the same floristic composition as above. F = 60%. A = 30%. C = 22%.	IV	Good	Bundhelkhand limestone and conglomerates	Slight slope	Reddish brown, sandy loam, 30-60 cm. deep.
3. An open mixed teak forest that has been highly disturbed. Teak has suffered much and most trees are stunted and gnarled. Only two layers are distinct. Middle tree layer of teak, <i>Acacia catechu</i> , <i>Cassia fistula</i> , <i>Butea monosperma</i> and <i>Saccopetalum tomentosum</i> . The shrub layer consists of <i>Carissa spinarum</i> , <i>Mimosa himalayana</i> and <i>Zizyphus anoplia</i> . F = 65%. A = 25%. C = 15%.	IV	Nil	Hametite	Plain ground	Reddish, sandy, and of very little depth about less than 15 cm.

Ramna Forest Reserve

1. A mixed teak stand with two layers only. The I & II lower composed of *Gardenia latifolia*, *Diospyros melanoxylon* and *Cassia fistula*; upper story of teak, *Butea monosperma*, *Saccopetalum tomentosum* and *Mitragyna parviflora*. Improvement fellings were carried out in 1939, when mature and malformed trees were removed. The sarub and the herb layers are absent.

F = 100%. A = 80%. C = 75%.

2. A mixed teak stand with teak completely exploited and with great abundance of bamboos. The latter was introduced in the last century and with the removal of the top story of teak, have become aggressive. Teak regeneration is made impossible due to the dense low shade, but in cleared areas coppice shoots have come up.

3. A mixed forest of *Anogeissus pendula* as the principal dominant and with sparse distribution of teak. Towards the west the stand composition changes appreciably with complete absence of teak and greater dominance of *Acacia catechu*.

Ghatara

1. A mixed teak stand, on the terraces of the banks of the river Biarna, a tributary of the Sonar. It is a protected forest with four prominent layers. Lower tree layer of *Alangium lamarkii*, *Flacourtia romanichi*; middle layer of *Gardenia latifolia*, *Aegle marmelos*, *Cassia fistula*; upper tree story of teak, *Holoptelea integrifolia*, and *Mitragyna parvifolia*. The shrub layer consists mainly of *Carissa spinarum* while the herb layer is composed of *Sida acuta*, *Malvastrum tricuspidatum* and *Cassia tora*.

F = 75%. A = 30%. C = 18%.

Nil	Alluvium	Plain with evidence of bad drainage	Dark clayey loam of good depth. Soil stiff and blackish.
III	Poor	Plain with good drainage	Light sandy loam of great depth and with lime nodules distributed through the profile.
IV	Poor	Slight slope	Reddish brown, sandy loam, porous and extending 30-45 cm. below the soil surface.
III	Good	Level with good drainage	Soil of considerable depth, sandy loam, light coloured with lime nodules.

TABLE V—(Continued)

Description and Composition	Quality	Regeneration	Geology	Topography	Soil
<p>2. A mixed teak stand on the slopes of a hill south-west of Ghatara. There is ample evidence of biotic disturbance and the forest is getting more open. The upper tree layer consists of teak, <i>Anogeissus pendula</i>, <i>Boswellia serrata</i>, <i>Sterculia urens</i> and <i>Acacia catechu</i>. The other layers are less prominent. F = 60%. A = 15%. C = 11%.</p>	IV	Poor	Vindhyan sandstone	Mid-slope	Shallow red, porous, sandy, not extending to more than 15-23 cm. below the surface.
<p><i>Sagar</i></p> <p>1. Mixed teak stand on the slopes of the plateau on black loam. The common associates in the upper tree level include <i>Terminalia tomentosa</i>, <i>Lannea grandis</i>, <i>Kydia calycina</i>, <i>Acacia catechu</i> and <i>Anogeissus latifolia</i>. F = 72%. A = 21%. C = 15%.</p>	III	Good	Trap	Mid-slope	Stabilised soil, extending about 90 cm. below the surface; blackish loam.
<p>2. A mixed teak stand associated with <i>Anogeissus latifolia</i>. Other details much as above. F = 64%. A = 18%. C = 15%.</p>	IV	Good	Trap	Plateau top	Red soils of about 45 cm. depth.
<p>3. Non-teak stand, forming an open shrubby forest that bears ample evidence of biotic ravages. <i>Butea monosperma</i> and <i>Diospyros melanoxylon</i> form principal dominants.</p>	Nil	Nil	Trap	Plateau top and slopes	Red soils and black loams, top soils in most cases usually badly eroded.

F = Frequency; A = Abundance; C = Cover (of teak).

TABLE VI
Soil Analysis*

Field Series	Moisture %	pH	Exch. CaO %	Exch. MgP_2O_7 %	Total avail. P*	Organic matter %	Organic carbon %	Nitrogen %	C/N
1	2	3	4	5	6	7	8	9	10
<i>Bori Reserves (June 1953)</i>									
1. 0" Depth	5.85	6.40	0.43	0.30	..	2.17	1.26	0.10	12.60
6"	11.92	6.00	0.36	0.50	7	2.07	1.20	0.07	17.14
1'	16.35	6.08	0.38	0.42	..	1.10	0.64	0.79	9.14
2'	17.05	6.01	0.37	0.44	..	1.17	0.68	0.06	11.33
3'	18.98	6.08	0.34	0.46	..	1.15	0.65	0.06	10.83
6"	11.05	6.66	0.51	0.35	18	2.89	1.68	0.13	12.92
2-A.	13.95	5.89	0.26	0.13	4	1.81	1.05	0.10	10.50
3.	12.56	5.94	0.35	0.15	7	2.62	1.50	0.13	11.70
4.	5.56	6.66	0.63	0.37	..	5.29	3.07	0.11	27.91
	10.92	6.14	0.49	0.42	5	2.03	1.18	0.08	14.75
	14.56	6.40	0.41	0.40	..	1.03	0.60	0.07	8.57
	15.92	6.00	0.38	0.36	..	0.83	0.48	0.07	6.86
6.	10.52	5.58	0.12	0.13	3	1.24	0.72	0.08	9.00
8.	10.02	5.40	0.23	0.14	3	1.42	0.83	0.08	10.37
9.	11.93	6.12	0.39	0.20	15	1.48	0.85	0.10	8.50
<i>Kheli Range (October 1953)</i>									
1.	..	6.95	0.52	0.37	..	3.55	2.06	0.14	14.72
	..	6.48	0.41	0.35	21	2.48	1.44	0.09	16.00
	..	6.52	0.31	0.27	..	1.33	0.97	0.07	13.86
	..	6.75	0.25	0.30	..	0.93	0.54	0.06	9.00
2.	..	6.20	0.35	0.37	18	2.41	1.40	0.10	14.00
3.	..	6.50	0.38	0.37	9	1.96	1.14	0.09	12.67
4.	..	6.00	0.23	0.20	3	2.03	1.18	0.11	10.73

TABLE VI—(Continued)

Field Series	Moisture %	pH	Exch. CaO %	Exch. Mg ₂ P ₂ O ₇ %	Total avail. P*	Organic matter %	Organic carbon %	Nitrogen %	C/N
1	2	3	4	5	6	7	8	9	10
<i>Allapalli Sub-Division (May 1953)</i>									
2.	6.25 10.57 13.42 12.59 7.56 14.42 18.96 16.58 5.96 16.05 20.25 19.95 18.46 12.54 14.65	6.24 6.32 6.30 6.02 6.38 6.00 6.10 6.18 6.80 6.40 6.54 6.51 6.30 6.25 5.96	0.27 0.30 0.33 0.30 0.30 0.28 0.30 0.38 0.75 0.84 0.79 0.72 0.65 0.34 0.28	0.25 0.41 0.43 .. 0.28 0.29 0.27 0.29 0.42 0.50 0.52 0.51 0.58 0.27 0.31	.. 7 4 4 5 5	2.24 1.50 1.21 .. 3.34 1.48 1.41 1.27 4.45 1.95 1.27 0.93 0.50 1.89 1.65	1.30 0.87 0.70 0.52 1.94 0.86 0.82 0.73 2.58 1.13 0.74 0.54 0.29 1.10 0.96	0.10 0.08 0.06 0.05 0.17 0.07 0.08 0.07 0.17 0.12 0.10 0.09 0.04 0.10 0.10	13.00 10.85 11.66 6.00 11.41 12.28 10.25 10.43 15.17 9.41 7.40 6.00 7.25 11.00 9.60
4.									
5.									
3.									
6.									
<i>Allapalli Sub-Division (September 1953)</i>									
9.	..	7.80	0.54	0.40	28	..	..	0.09	..
10.	..	6.58	0.59	0.29	7	..	..	0.09	..
11.	..	6.00	0.22	0.23	9	..	..	..	..
12.	..	6.01	0.23	0.21	15	..	..	..	..
<i>Punnasa Range (April 1953)</i>									
1.	12.49	6.80	0.99	0.45	9	1.59	0.92	0.09	10.27
2.	5.65 12.90	7.18 7.10	0.55 0.60	0.60 0.60	.. 7	2.89 1.83	1.68 1.06	0.15 0.12	11.20 8.83

TABLE VI—(Continued)

Field Series	Moisture %	pH	Exch. CaO %	Exch. $Mg_2P_2O_7$ %	Total avail. p*	Organic matter %	Organic carbon %	Nitrogen %	C/N
1	2	3	4	5	6	7	8	9	10
				<i>Ghatra (October 1953)</i>					
1.	15.56	7.25	0.86	0.40	24	2.79	1.62	0.14	11.57
2.	8.40	6.25	0.42	0.18	4	2.46	1.43	0.13	11.00
			<i>Shahgarh Banda Range (August 1953)</i>						
1.	..	6.30	0.58	0.25	7	1.86	1.08	0.09	12.00
2.	..	6.20	0.58	0.25	9	1.45	0.84	0.07	12.00
3.	..	6.00	0.31	0.20	5	1.51	0.88	0.09	9.78
			<i>Sagar (March 1953)</i>						
1.	9.70	6.85	0.53	0.30	..	3.96	..	..	..
	16.56	6.80	0.53	0.33	7	2.85	..	..	..
	18.96	6.85	0.53	0.35	..	2.04	..	..	..
	20.00	6.85	0.50	0.29	..	1.14	..	..	..
	..	8.05	1.95	..	..	..	..	..	..
2.	10.60	7.05	0.58	0.36	..	4.50	..	..	..
	14.52	6.75	0.50	0.32	5	2.21	..	..	..
	19.00	7.00	0.52	0.38	..	2.13	..	..	..
	..	7.45	0.68	0.42	..	1.35	..	..	..
3.	4.98	6.00	0.37	0.27	..	0.46	..	..	..
	10.30	5.70	0.27	0.20	3	1.69	1.43	0.10	14.30
	12.60	5.99	0.27	0.14	..	1.17	0.98	0.09	10.88
	10.80	6.15	..	..	..	..	0.68	0.07	8.71
		

* Mg. per 100 gm. of the soil.

TABLE VII

Frequency of Teak Quality and Regeneration Classes in pH Classes

pH Ranges	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5
	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0
1*	..	..	23†	16	7	1	8	3
2	..	1	10	5	4	1	1	..
3	1	11	5	..	..	..	..	..
4	1	1	18	11	5	2	2	..
5	..	13	9	9	1	0	1	..
5B	..	13	7	4	..	..	..	..

* 1 = Good teak growth.

2 = Medium teak growth.

3 = Poor teak growth, or absent.

4 = Good regeneration

5 = No regeneration

} Based upon top soil only.

† No. of samples within each pH class.

TABLE VIII

pH Values and Their Frequency in Soil Profiles for Growth and Regeneration Classes

Depth	1	2	3*
0"	6.73 (11)†	7.36 (2)	5.99 (2)
.6"	6.63 (11)	7.09 (2)	5.74 (2)
1'	6.82 (11)	6.86 (2)	5.94 (2)
.2'	6.90 (11)	7.42 (2)	5.94 (2)
3'	7.23 (6)	..	..
4'	8.62 (2)	..	..

* Growth and regeneration classes.

† Figures in brackets are the numbers of the profiles studied.

TABLE IX

*Frequency of Teak Quality and Regeneration Classes
in Exchangeable Calcium Classes*

Calcium Ranges	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	Above
1*	..	4†	17	4	10	4	4	3	12
2	..	2	6	4	5	2	1	1	1
3	3	10	4	..	..	..	..	..	..
4	..	6	7	6	12	1	2	3	3
5	1	14	7	2	3	1	2	1	3
5B	1	13	5	2	3	..	..	..	..

* Growth and regeneration classes.

† No. of samples within each calcium class.

TABLE X

*Exchangeable Calcium Values and Their Frequency in the
Soil Profiles for Growth and Regeneration Classes*

Depth of Soil	1	2	3*
0"	0.54 (11)†	0.53 (2)	0.31 (2)
6"	0.81 (11)	0.50 (2)	0.25 (2)
1'	0.84 (11)	0.55 (2)	0.26 (2)
2'	0.94 (11)	0.77 (2)	0.18 (1)
3'	1.55 (6)	..	..
4'	2.86 (2)	..	..

* Growth and regeneration classes.

† Figures in brackets are the numbers of the profiles studied.

TABLE XI

Frequency of Teak Stands of Different Growth and Regeneration Classes in Percentage Classes of Exchangeable Magnesium

Mg ranges	0.1	0.15	0.20	0.25	0.30	0.35	0.40	0.45	0.50
	0.15	0.20	0.25	0.30	0.35	0.40	0.45	0.50	0.60 & above
1*	..	..	2†	11	10	10	14	3	5
2	..	..	2	4	4	4	2	1	4
3	8	4	4	1	..	..	..	..	..
4	1	1	5	4	6	10	7	3	3
5	6	7	2	9	4	..	3	1	2
5B	6	6	2	6	1	..	2	..	1

* Growth and regeneration classes.

† No. of samples within each magnesium class.

TABLE XII

Magnesium Values and Their Frequency in Soil Profiles for Different Growth and Regeneration Classes

Depth of Soil	1	2	3*
0"	0.33 (11)†	0.41 (2)	0.21 (2)
6"	0.39 (11)	0.38 (2)	0.17 (2)
1'	0.41 (11)	0.42 (2)	0.13 (2)
2'	0.38 (9)	0.30 (2)	0.11 (2)
3'	0.42 (5)	..	..
4'	0.42 (2)	..	..

* Growth and regeneration classes.

† Number of profiles studied.

TABLE XIII

Frequency of Teak Stands of Different Growth and Regeneration Classes in Phosphates Classes

Phos. ranges	$\frac{3}{4}$	$\frac{4}{5}$	$\frac{5}{7}$	$\frac{7}{9}$	$\frac{9}{15}$	$\frac{15}{25}$	$\frac{25}{\text{Above}}$
1*	..	2†	3	4	4	.6	1
2	..	..	2	5	3	1	2
3	6	2	2	1	..	..	..
4	1	3	6	6	3	5	1
5	8	4	4	2	1	..	1
5B	8	4	2	2	1	..	..

* Growth and regeneration classes.

† No. of samples within each phosphate class.

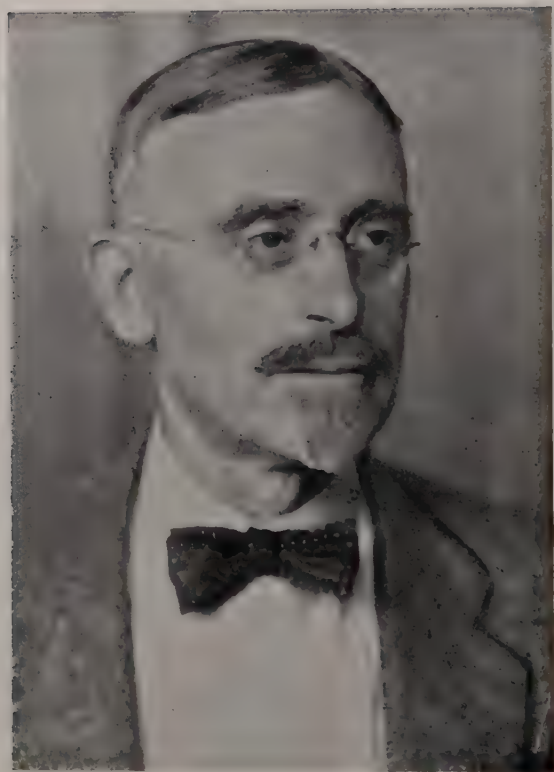
TABLE XIV

Moisture Percentage and Their Frequency in the Soil Profiles for the Different Growth and Regeneration Classes

Depth of Soil	1	2	3*
0"	6.76	5.65	4.77
6"	13.58	12.90	10.18
1'	16.84	15.00	12.30
2'	18.07	15.12	9.42
3'	19.82	..	..
4'	20.01 (6)†	.. (1)	.. (2)

* Growth and regeneration classes.

† Number of profiles studied.



A. F. BLAKESLEE

ALBERT FRANCIS BLAKESLEE (1874-1954)

PROFESSOR A. F. BLAKESLEE was born in Geneseo, N.Y., in 1874. Although I had heard of him even in 1921 (when I was student of the Intermediate class) as the discoverer of heterothallism in fungi, it is only in 1945-47 that I had the pleasure of coming in personal contact with him at several places in the U.S.A. including his laboratory at the Smith College where I enjoyed his hospitality for several days. Indian botanists will recall his visit to this country as foreign delegate to the Indian Science Congress of 1947 when he also received the honorary degree of Doctor of Science of the University of Delhi.

Blakeslee took his Bachelor's Degree in 1896 from the Wesleyan University at Middletown, Conn., after which he taught mathematics and science for three years. In 1899 he joined the Harvard University and took courses in botany and zoology. Botany interested him specially and after taking the Master's Degree he started research in mycology under the directions of Ronald Thaxter taking his Ph.D. in 1904. The thesis "Sexual reproduction in the Mucorineæ" was published in 1904 in the Proceedings of the American Academy of Arts and Sciences. A voluminous work, it at once attracted worldwide recognition. In this Blakeslee showed for the first time that in many members of Mucorales there are two sexes, each capable of almost indefinite perpetuation by means of asexual spores, but producing zygosporangia only when the mycelium of one comes in contact with the other. These he called heterothallic forms in contrast to the homothallic ones in which zygosporangia are formed within the same mycelium.

Aided by a research grant from the Carnegie Institution of Washington, Blakeslee visited Klebs, the well-known German Physiologist, at Halle, in 1904-06, and returned as Instructor in Botany at Harvard and Radcliffe for one year. In 1907 he became professor of Botany in what soon developed into the Connecticut Agricultural College, and was later appointed Head of the Department of Botany and Genetics. Here he became interested in many other things besides fungi—the domestic fowl, *Rudbeckia*, beans, *Datura*, corn and sugar maple. Even systematic botany did not fail to attract him and he published a bulletin on "New England Trees in Winter" which later appeared in book form as "Trees in Winter".

An excessive amount of teaching and administrative work often hampers an active mind and in 1915 Blakeslee exchanged his professorship for a position as resident investigator in plant genetics at the Carnegie Station for Experimental Evolution, Long Island, N.Y. The name was changed in 1921 to Department of Genetics, Carnegie Institution of Washington. In 1923 he was made Assistant Director and in 1936, Director, retiring from this position in 1941 at the age of 67. Here with six glasshouses and a large plot of land at his disposal Blakeslee exchanged his first love, incompatibility or heterothallism in fungi, for the genetics of higher plants. He worked on *Portulaca*, *Rudbeckia*, *Melandrium* and *Nicotiana* but most of all *Datura*. For

the sake of inciting some fun, he would often attend meetings, with a flower of *Datura* in his button hole. His publications on the methods of inducing polyploidy attracted even greater attention than did the paper on heterothallism. A great deal of newspaper publicity was given to colchicine and many exaggerated claims were made about its efficacy. For instance, some people thought that it could be used to grow hair on the head and to create a race of supermen. For such claims, of course, Blakeslee had no responsibility whatsoever.

It must be remembered that Blakeslee was not the first to discover the effect of colchicine on dividing nuclei nor did he claim this distinction. A. P. Dustin (1934) of Brussels first reported its action in arresting nuclear division. Within 3 years after that, Eigsti, Nebel and Blakeslee were all on this track and a voluminous literature has appeared on the subject during the last 18 years.

After retirement from the Carnegie Institution, Blakeslee was invited to the Smith College, Northampton, a women's institution from which his wife had graduated in 1906 and where she taught from 1906 to 1909. His collections of *Datura* and *Rudbeckia* naturally came with him. Smith College was not a place with any special traditions or facilities for genetical research, but with his usual energy and determination Blakeslee immediately set out to organize work in the new headquarters. With his high prestige and the great influence he commanded in the country he obtained small grants from a number of organizations and soon had a team of young men and women working under his directions. One Indian student, P. C. Joshi (now at the Government College, Hoshiarpur), also took his doctorate under him.

Having already found a method for doubling the number of chromosomes at will, Blakeslee's sharp mind turned to haploid plants as possible sources for diploid homozygous offspring. The chief difficulty lay in finding a method for inducing the haploid egg to divide. As early as 1921, Blakeslee and his co-workers had identified a spontaneous haploid in *Datura* and later found many other such cases but nothing could be said about the factors responsible for their occurrence. Blakeslee tried to stimulate the unfertilized egg to divide by injecting several chemical substances into the ovary of *Datura* and other plants but the attempt was unsuccessful and only tumorous outgrowths resulted by a proliferation of the cells of the endothelium. The production of haploids by artificial methods still remains a challenge and Blakeslee never failed to invite the attention of visitors to his laboratory to this much desired need of plant breeders and geneticists.

At the Smith College, Blakeslee's major interest seemed to be in the control of fertilization, *i.e.*, the removal of the barriers to crossability in plants, and in physiological studies concerned with the artificial culture of embryos. *Datura* was a useful tool for this research. For convenience he distinguished the barriers to crossability into two classes: (a) pre-fertilization barriers such as lack of germination of pollen grains, bursting or slow growth of pollen tubes, and (b) post-fertilization barriers involving inability of the fertilized eggs to develop into a viable embryo.

Recently Blakeslee also became interested in the effect of thermal neutrons and of nuclear detonations on the mutation rate of *Datura* where seeds were exposed to such radiations.

Professor Blakeslee's scientific achievements and energy, accompanied by his unfailing humour and cordiality, made him a truly great scientist. In one of his articles (*Scientific Monthly*, February 1948) he wrote: "I should like to be a Maharaja, not because of the great wealth and multiplicity of wives or their equivalents, with accompanying luxurious living, but rather for the good that I might do by means of Science and its application."

P. MAHESHWARI.

GEORG TISCHLER (1878-1955)

PROFESSOR GEORG TISCHLER was born on June 22, 1878, in Losgehn where his family had an estate since 1872. Already as a boy of 10 years he had begun to make collections of plants which he continued for the whole of his life. For his College and University career he studied at Königsberg under Luerisson (1896-97), at Munich under Goebel and Solereder (1897-98), and at Bonn under Strasburger (1898-99). At Bonn there was also Schimper, the well-known ecologist. These were all distinguished teachers, the seed fell on fertile soil, and Tischler grew up to be quite an all-rounder although with a special bias for cytology. While at Bonn he submitted his thesis for the Ph.D. bearing the title "Über die Verwandlung der Plasmastränge in Cellulose im Embryosack bei *Pedicularis*". In 1900 he became assistant at the Botanical Institute, Heidelberg, under Prof. Ernst Pfitzer (1900-06) and Prof. Georg Klebs (1907-12). Pfitzer was a morphologist and taxonomist, and Klebs a physiologist. During this period Tischler also got opportunities to go abroad. In 1903 he visited Jacob Eriksson (author of the ill-fated Mycoplasma Theory) at the Phytopathological Institute of the Landsbruksakademie of Stockholm. In the following year he went to Nancy (France) to study some mycological problems with Professor Vuillemin and in 1908 secured a research fellowship for going to the tropics. He spent about 9 months visiting Buitenzorg, Peradeniya and Amane in East Africa, which he considered to be a wonderful experience. In fact in the Germany of those days nobody could expect to be made Professor Ordinarius (Full Professor) without some experience of travel and collection in the tropics.

In 1912 Tischler was promoted to the professorship and directorship of the Botanical Institute at Braunschweig; in 1917 he went over to Hohenheim, Stuttgart; and in 1922 to Kiel. He held the directorship of the Botanical Garden and Institute at Kiel for 30 years until his retirement in 1951.

While at Hohenheim, Tischler published the first edition of his "Pflanzenkaryologie", and his fame was high enough in 1926 to merit his election to the presidentship of the Cytology Section of the International Botanical Congress held at Ithaca, N.Y. From now on the way was opened for him for further travel which he greatly enjoyed especially as he was a good linguist and could talk fluently in English. In 1929 he went to France and Italy and in 1930 to Cambridge to attend the next International Botanical Congress. In 1930 he received an invitation from the Johns Hopkins University, Baltimore, to give a course of lectures on Cytology. Similar invitations soon came from several other Universities in the U.S.A.

In 1934 appeared the first volume of the new edition of his "Pflanzenkaryologie" and in 1935 he was again called upon to preside over the Cytology Section of the International Botanical Congress at Amsterdam.



GEORG TISCHLER

By this time Tischler was sufficiently well known even in India. I began exchanging publications with him and occasionally sought his help for references to literature. His replies were always so prompt and encouraging that in 1936 I decided to take study leave from my post as Associate Professor of Botany at Agra College to spend some time with him and a few other German botanists.

I found Tischler's knowledge of cytology and embryology to be so vast and encyclopædic that under his patronage I felt encouraged to write a review of embryo sac types which was published in 1937 in the *New Phytologist*.

Tischler attended several other International Congresses: in 1939 at Edinburgh; in 1950 at Stockholm; in 1953 at Bellagio, Italy; and in 1954 at Paris. I had the pleasure of meeting him both at Stockholm and at Paris.

Honours came to him richly in other ways also. He was Honorary member of the Botanical Society of Japan; of the Indian Botanical Society; of the National Institute of Sciences, India; and of several other bodies.

Tischler's scientific work covered a wide range—fungi, embryology and cytology. His interests after 1925 were, however, mainly in nuclear cytology or karyology. He published many papers on chromosome numbers, polyploidy, the relation between cytology and taxonomy, and between polyploidy and ecology. A new edition of his book came out only a few years ago and he functioned for a long time as editor of the series of volumes published under the title "*Handbuch der Pflanzenanatomie*" originated by Linsbauer. His last manuscript "*Angewandte Pflanzenkaryologie*", left in manuscript form, is now being completed by his pupil Professor H. D. Wulff.

To-day many of the pupils of Professor Tischler are themselves holding professorial posts in various institutions in Germany. Amongst Indians who studied with him there are, besides the writer, Dr. S. P. Kapoor (Poona), Dr. T. S. Raghavan (Coimbatore), Dr. N. Krishnaswamy (Coimbatore).

P. MAHESHWARI.

By this time Thomas was exhibiting well known signs of being a person of extraordinary gifts and a very high capacity for self-culture in literature. His tastes were always on the high and commanding level. He was a student of the great poets of the English language, and a student of the great poets of the English language, and a student of the great poets of the English language.

I found Thomas's knowledge of English and literature to be so vast and comprehensive that when he came to the subject of the history of the English language, he was able to write a volume of English and literature which was published in 1907 in the New York edition.

Thomas's interest in the history of the English language was not only a matter of fact, but a matter of fact. He was a student of the history of the English language, and a student of the history of the English language, and a student of the history of the English language.

Thomas came to him in his early days, and he was a member of the National Society of Science, and a member of the National Society of Science, and a member of the National Society of Science.

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G. Thomas